THE NEXT TSUNAMI
Where Will It Hit?

DA VINCI DISCOVERY
Is It the Real Deal?

VERMILION CLIFFS
A Southwestern Secret

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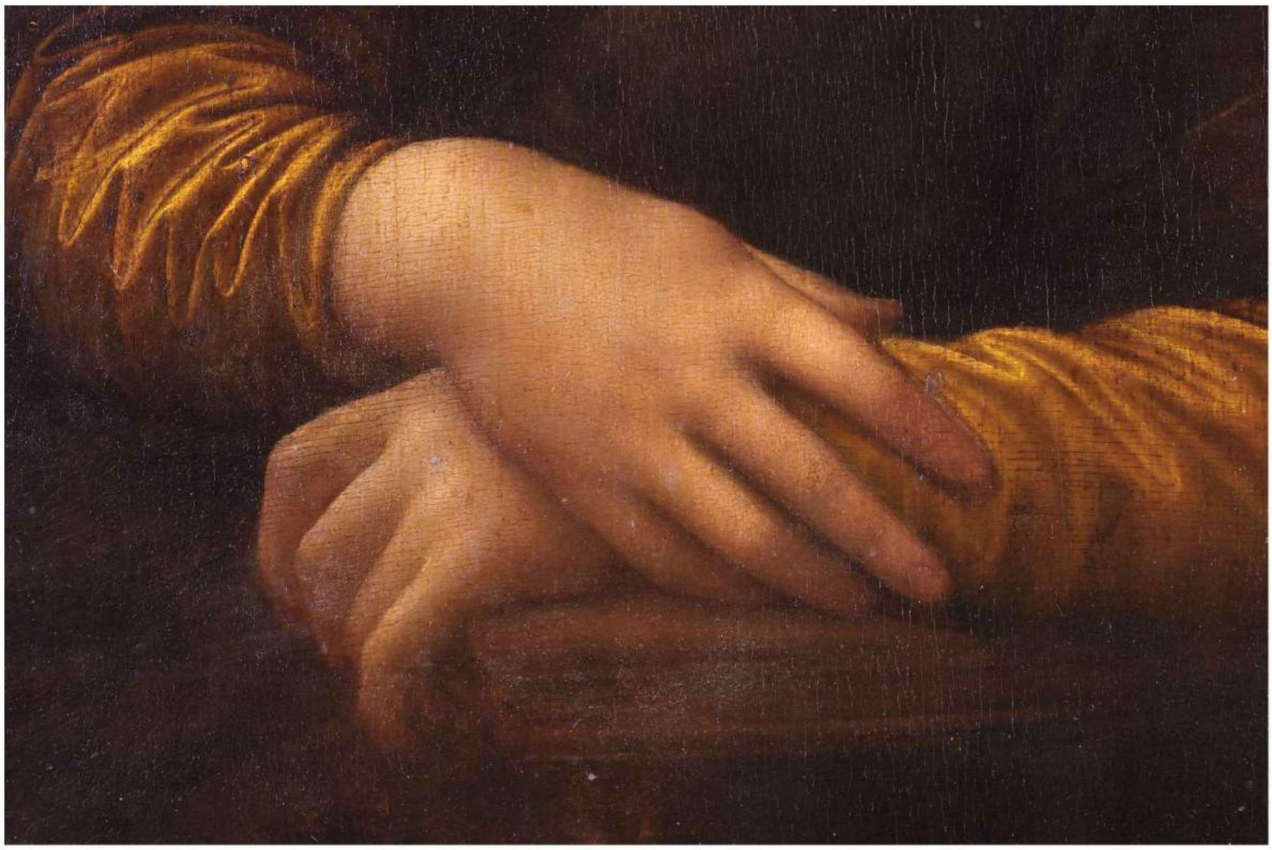
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VOL. 221 • NO. 2

NATIONAL GEOGRAPHIC

A deejay urged, in English, "Everybody get crazy! Ziss iz bikini party!"
page 94



PASCAL COTTE, SIPA PRESS

The hands of the "Mona Lisa" reveal the delicacy in Leonardo da Vinci's portraits. Now there may be one more woman to add to his list: "La Bella Principessa."

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They came to meet Papua New Guinea's nomads—and stumbled into a life-and-death crisis.
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Barking Dogs Never Pose
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Enter the Vermilion Cliffs
A lottery admits 20 people a day to see the Wave, a swirling rock formation at the national monument. How do you get on the list?
ngm.com + iPad

Field Test
Follow photographer Michael "Nick" Nichols as he tracks lions in the Serengeti.
ngm.com

On the Cover
Penny, born January 27, 2004, is the great-great-great granddaughter of the famously photographed Weimaraner Fay Ray. Says Wegman: "She is the quietest and stillest and most reliable of my dogs."
Photo by William Wegman

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Indian Water Buffalo *(Bubalus arnee)*
Size: Head and body length, 2.4 - 3 m (7.9 - 9.8 feet); shoulder height, 1.5 - 1.9 m (4.9 - 6.2 feet); tail, 0.6 - 1 m (2.0 - 3.3 feet) **Weight:** Approx. 700 - 1,200 kg (1,500 - 2,600 lbs) **Habitat:** Prefers low-lying alluvial grasslands, riparian forests and woodlands **Surviving number:** Estimated at fewer than 2,500 mature individuals

Photographed by Sandesh Kadur

WILDLIFE AS CANON SEES IT

A dangerous mix. As habitat loss brings the Indian water buffalo closer to its cousin the domestic water buffalo, their union results in hybridized offspring that threaten the gene pool. Highly social, these prodigious grazers usually live in loosely structured maternal groups made up of females, their dependent young and a bull. Adult males not attached to such a group sometimes form groups of their own. But the urge to mingle is hazardous when wild and domestic meet—due to not only hybridization, but also diseases that can spread to wild populations. The two worlds have gotten too close for comfort.

As we see it, we can help make the world a better place. Raising awareness of endangered species is just one of the ways we at Canon are taking action—for the good of the planet we call home. Visit **canon.com/environment** to learn more.

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By the Treacherous Sea

"Never turn your back to the sea," my mother used to tell me over the roar of the surf. She'd read about rogue waves coming in and sweeping children away, but I loved the magic I felt at the edge of the ocean and never gave her warning much thought as I ran up and down the beach exploring tide pools. That changed on Good Friday in 1964, when I was 12 years old. Just 25 miles south of my grandparents' beach cottage in Harbor, Oregon, a tsunami created by the largest recorded earthquake in North America swept down the Pacific Northwest coast with the speed of a jet and slammed into Crescent City, California. The photos of the carnage, so close to home, were staggering. Ten people from the community of 3,000 perished. "It was like a violent explosion," one witness reported. "The whole beachfront moved, changing before our very eyes."

Photos of the carnage were staggering.



Crescent City, 1964: "Buildings, cars, lumber, and boats shifted around like crazy," said a witness.

This month author Tim Folger dissects the geophysics of tsunamis and explains how they have shaped civilization for thousands of years. More than 3,500 years ago a volcanic eruption in the Aegean Sea generated a tsunami that inundated Mediterranean shores. Last year's massive tsunami in northeastern Japan killed some 16,000 and erased entire towns and villages from the map. No one, Folger says, ever expected Japan—with all its elaborate preparations—to be so vulnerable, but sometimes nature's fury overwhelms our most carefully crafted defenses. After reading his piece, I am even less inclined to turn my back to the sea.

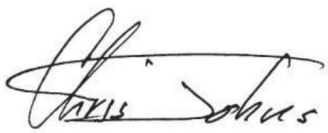
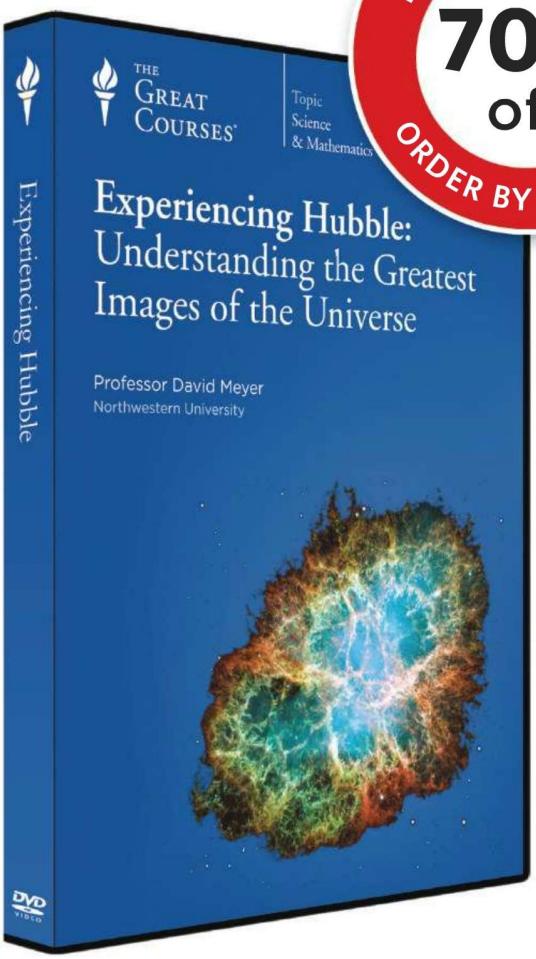


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10. Abell 2218—A Massive Gravitational Lens
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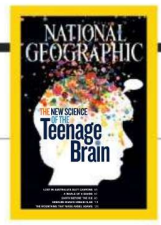
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The Teenage Brain

Could the brain rewiring described by David Dobbs be a sign of aging? After all, our ancestors hundreds of thousands of years ago barely surpassed adolescence, meaning that the brain was designed to peak then. Maybe what happens to the brain during adulthood is no more than a brain trick to keep some efficiency and adapt to the unexpected survival. And that question brought a second thought: The leap from early hominids to humans, and the subsequent conquest of the world, was done by teenagers. We must look at young people with more respect; they have powerful minds.

BRUNO BENAVIDES
Baltimore, Maryland

Two quotes from the article: "The more you seek novelty and take risks…the better you do," and "this age group dies of accidents of almost every sort…at high rates." Interesting. We haven't really improved on Aristotle at all.

HAROLD LAFONT
Aptos, California

Most of these behaviors seem to fit males more than females. I found no clue whether any attempt has been made to distinguish between them—or to nullify such a distinction.

JAN EAGLE
Tucson, Arizona

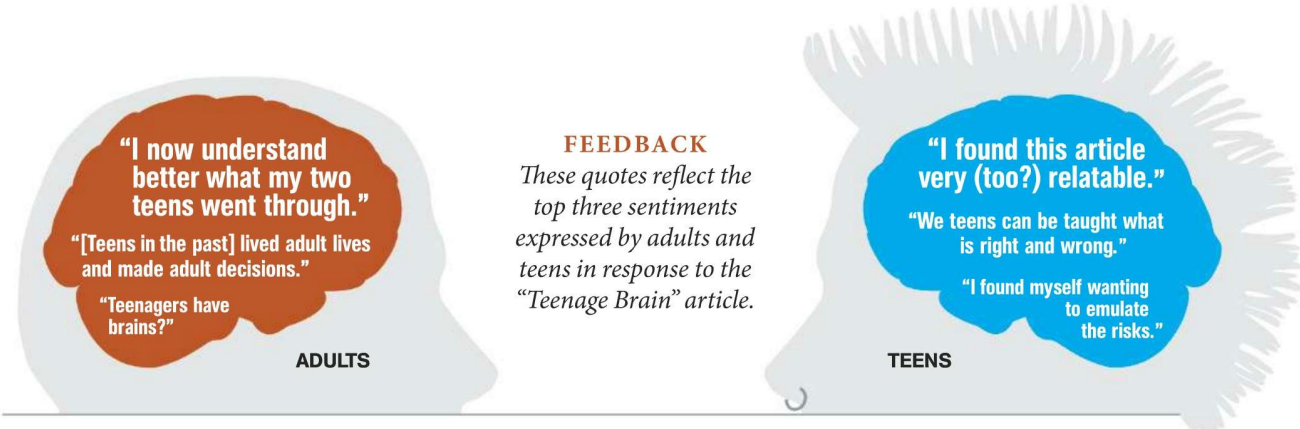
I was a foster parent for over 40 years. More than a hundred teenagers passed through my home in that time, not including their friends and families. I have come to see teenagers as inquisitive, impulsive, adventuresome, and an excellent cure for boredom. What really astounds me is that this population, our children, constitutes the only group left that mainstream media can insult with impunity. In general, their resilience is quite amazing.

HARRY H. SNYDER III
Whiting, Maine

When, as a 17-year-old, I take a risk, it is to experience reward, but we aren't the metaphor of a dog being led by a bone you've made us out to be. I take risks to reap the reward of furthering my education. When I drive down the road at 113 miles an hour, I'm considering the consequences, but I'm also discovering how far I can push myself and the traction-controlled rocket that could propel me to my death. When hurling toward a lacrosse goal, I want to know how many g's I can really pull in a direction change before falling.

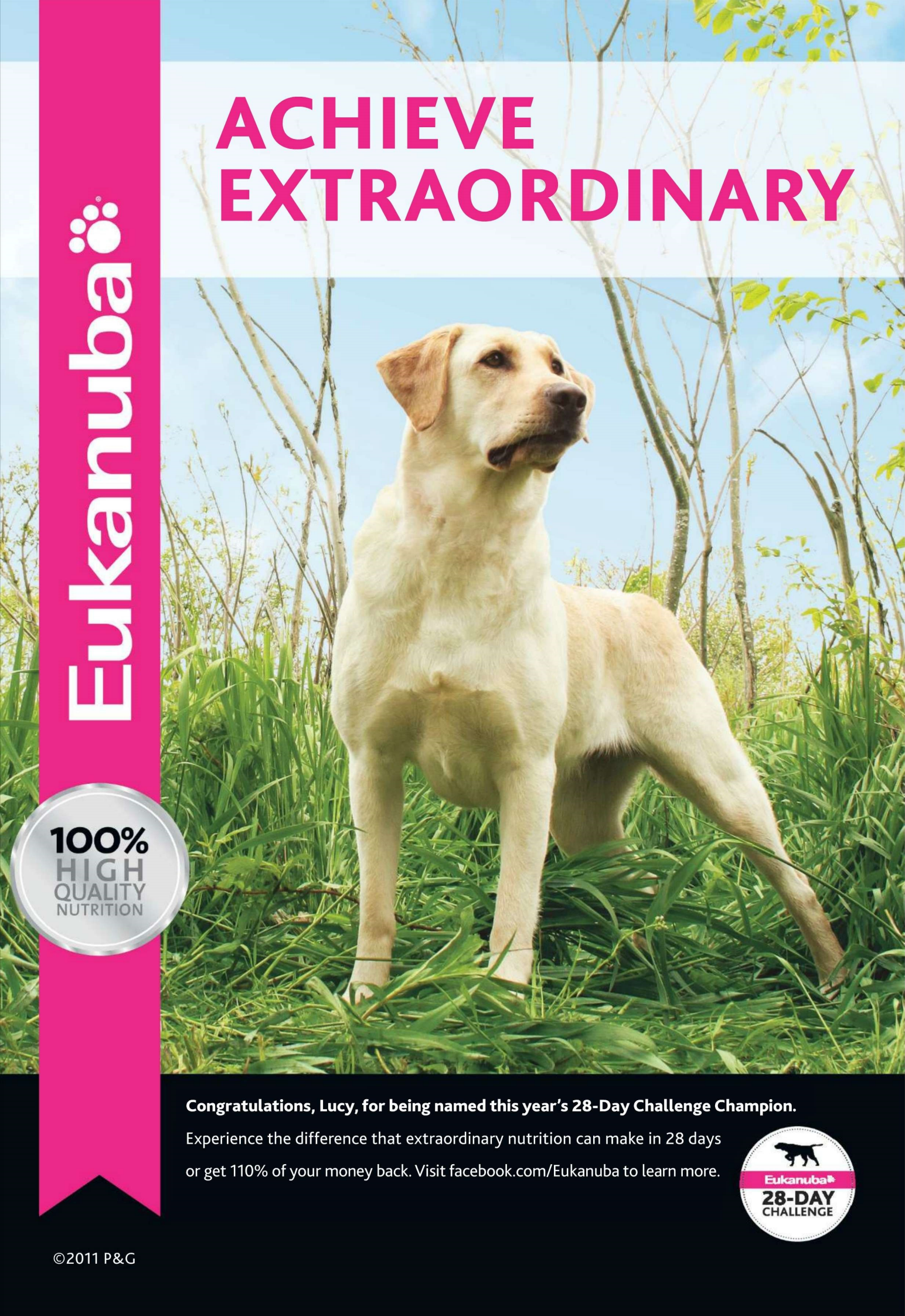
BRADY ATWOOD
Midway, Kentucky

Corrections
OCTOBER 2011: WORLD WITHOUT ICE
Page 98: The Okefenokee Swamp is primarily in Georgia, not Florida.
Page 109: Camels are artiodactyls, not perissodactyls.



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Dean Potter gets ready for a flight atop the Stawamus Chief dome in Squamish, British Columbia.

THIS MONTH

Human Flight

Climber and BASE jumper Dean Potter has dropped 8,900 feet in the Swiss Alps, setting the record by soaring in his wing suit for just under three minutes. Now he aims even higher: to jump from Mount Bute, a 9,200-foot peak that towers near the British Columbia coastline. Follow Potter from his base in Yosemite to Florida, where he's fitted for a new, custom-made wing suit, and to Montana, where he gets tips from a bird biologist. Training is intense. Techniques must be perfect. Will the plan take flight? Tune in to the National Geographic Channel to find out.

NATIONAL GEOGRAPHIC CHANNEL



NAT GEO WILD

Wild Mississippi

Prepare for a rollicking ride in this new series, which explores North America's biggest river system and celebrates the wildlife—from bobcats to boars to great gray owls (above)—living within it.

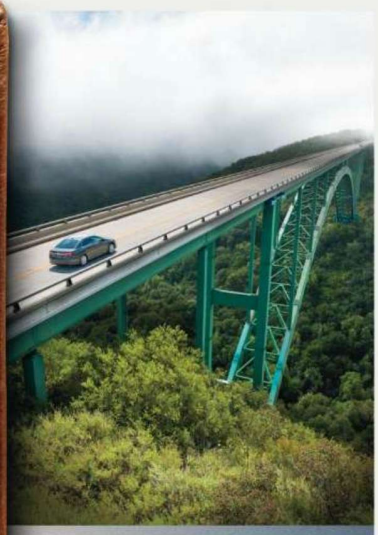
For listings go to **natgeotv.com** and **natgeowild.com.**

PHOTOS: JIMMY MARTINELLO (TOP); STAN BOUSSON, NGC

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Prototype shown with optional equipment. Production model may vary. 1.Voice-activation for all Entune™ apps available spring 2012. 2. Be sure to obey traffic regulations and maintain awareness of road and traffic conditions. Select Entune™ apps use a large amount of data and you are responsible for all data charges. Apps and services vary by phone and carrier. Not all apps and data services are available initially. Apps identified by "TM" or "®" are trademarks or registered trademarks of their respective companies and cannot be used without permission. See toyota.com/entune for the latest information regarding apps and services. 3. Entune™ available on SE, XLE and Hybrid XLE models only. ©2011 Toyota Motor Sales, U.S.A., Inc.



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Oceanographer Enric Sala—a National Geographic explorer-in-residence—encounters an endangered dusky grouper.

MISSION *To restore the oceans' health and protect pristine areas*

Founded in 1888, the National Geographic Society has added to our knowledge of earth, sea, and sky by supporting more than 10,000 explorations and research projects. Readers' membership dues make this support possible.

Ocean Advocate

As a child, I learned to snorkel before I knew how to swim. My first clear memory is of seeing a red starfish one summer off Spain's Costa Brava. My family's experience with fish was mostly on the stove—they ran a restaurant. But I watched the documentaries of Jacques-Yves Cousteau and dreamed of being a diver on his *Calypso.*

I assumed as a child that big fish belonged only to exotic, tropical seas. I didn't see them in the Mediterranean I knew. But years later, in that same sea's Medes Islands Marine Reserve, I finally saw all the fish I'd never seen before: sea bream, corvina, grouper. I saw all that had been lost to overfishing and pollution and realized that the whole Mediterranean must once have been like this.

That is when I decided to work on creating marine reserves. These protected areas benefit fish and people. After many years sea life can recover to levels similar to those in pristine areas. Fishermen gain too. At one Kenya fishery their incomes have doubled because of marine reserves.

In recent years I've helped inspire leaders to create marine protected areas off Chile, Costa Rica, Belize, and the United States. But more needs to be done to restore ocean health: We need to better manage our unsustainable fisheries, improve aquaculture, and enforce marine-pollution laws.

My happiest moments are underwater, especially in places with large predators. If there are predators, it means there is more of everything, and I know the waters are healthy. *—Enric Sala*

PHOTO: JOSEP CLOTAS

For arthritis patients, it's simple physics:

A body in motion tends to stay in motion.



Celebrex can help relieve arthritis pain...so you can keep moving.

Staying active can actually relieve arthritis symptoms. But if you have arthritis, staying active can be difficult. Celebrex can help relieve arthritis pain...so *your* body can stay in motion.

- **Just one 200mg Celebrex a day can provide 24-hour relief for many with arthritis pain and inflammation.***
- **Celebrex is proven to improve pain, stiffness and daily physical function in clinical studies.****
- **Celebrex is not a narcotic.**

When it comes to finding the right arthritis treatment for you, you and your doctor need to balance the benefits with the risks. So ask your doctor about prescription Celebrex. It could be an important step towards keeping *your* body in motion.

Visit **celebrex.com** or call 1-888-CELEBREX for more information.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

*Individual results may vary. **Clinical studies with osteoarthritis patients.

Important Safety Information:

All prescription NSAIDs, like CELEBREX, ibuprofen, naproxen and meloxicam have the same cardiovascular warning. They may all increase the chance of heart attack or stroke, which can lead to death. This chance increases if you have heart disease or risk factors for it, such as high blood pressure or when NSAIDs are taken for long periods.

CELEBREX should not be used right before or after certain heart surgeries.

Serious skin reactions, or stomach and intestine problems such as bleeding and ulcers, can occur without warning and may cause death. Patients taking aspirin and the elderly are at increased risk for stomach bleeding and ulcers.

Tell your doctor if you have: a history of ulcers or bleeding in the stomach or intestines; high blood pressure or heart failure; or kidney or liver problems.

CELEBREX should not be taken in late pregnancy.

Life-threatening allergic reactions can occur with CELEBREX. Get help right away if you've had swelling of the face or throat or trouble breathing. Do not take it if you've had an asthma attack, hives, or other allergies to aspirin, other NSAIDs or certain drugs called sulfonamides.

Prescription CELEBREX should be used exactly as prescribed at the lowest dose possible and for the shortest time needed.

See the Medication Guide on the next page for important information about Celebrex and other prescription NSAIDs.

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Medication Guide
for
Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

(See the end of this Medication Guide for a list of prescription NSAID medicines.)

What is the most important information I should know about medicines called Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

NSAID medicines may increase the chance of a heart attack or stroke that can lead to death.

This chance increases:

- with longer use of NSAID medicines
- in people who have heart disease

NSAID medicines should never be used right before or after a heart surgery called a "coronary artery bypass graft (CABG)."

NSAID medicines can cause ulcers and bleeding in the stomach and intestines at any time during treatment. Ulcers and bleeding:

- can happen without warning symptoms
- may cause death

The chance of a person getting an ulcer or bleeding increases with:

- taking medicines called "corticosteroids" and "anticoagulants"
- longer use
- smoking
- drinking alcohol
- older age
- having poor health

NSAID medicines should only be used:

- exactly as prescribed
- at the lowest dose possible for your treatment
- for the shortest time needed

What are Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

NSAID medicines are used to treat pain and redness, swelling, and heat (inflammation) from medical conditions such as:

- different types of arthritis
- menstrual cramps and other types of short-term pain

Who should not take a Non-Steroidal Anti-Inflammatory Drug (NSAID)?

Do not take an NSAID medicine:

- if you had an asthma attack, hives, or other allergic reaction with aspirin or any other NSAID medicine
- for pain right before or after heart bypass surgery

Tell your healthcare provider:

- about all of your medical conditions.
- about all of the medicines you take. NSAIDs and some other medicines can interact with each other and cause serious side effects. **Keep a list of your medicines to show to your healthcare provider and pharmacist.**
- if you are pregnant. **NSAID medicines should not be used by pregnant women late in their pregnancy.**
- if you are breastfeeding. **Talk to your doctor.**

What are the possible side effects of Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)?

Serious side effects include:

- heart attack
- stroke
- high blood pressure
- heart failure from body swelling (fluid retention)
- kidney problems including kidney failure
- bleeding and ulcers in the stomach and intestine
- low red blood cells (anemia)
- life-threatening skin reactions
- life-threatening allergic reactions
- liver problems including liver failure
- asthma attacks in people who have asthma

Other side effects include:

- stomach pain
- constipation
- diarrhea
- gas
- heartburn
- nausea
- vomiting
- dizziness

Get emergency help right away if you have any of the following symptoms:

- shortness of breath or trouble breathing
- chest pain
- weakness in one part or side of your body
- slurred speech
- swelling of the face or throat

Stop your NSAID medicine and call your healthcare provider right away if you have any of the following symptoms:

- nausea
- more tired or weaker than usual
- itching
- your skin or eyes look yellow
- stomach pain
- flu-like symptoms
- vomit blood
- there is blood in your bowel movement or it is black and sticky like tar
- skin rash or blisters with fever
- unusual weight gain
- swelling of the arms and legs, hands and feet

These are not all the side effects with NSAID medicines. Talk to your healthcare provider or pharmacist for more information about NSAID medicines.

Call your doctor for medical advice about side effects. You may report side effects to FDA at 1-800-FDA-1088.

Other information about Non-Steroidal Anti-Inflammatory Drugs (NSAIDs)

- Aspirin is an NSAID medicine but it does not increase the chance of a heart attack. Aspirin can cause bleeding in the brain, stomach, and intestines. Aspirin can also cause ulcers in the stomach and intestines.
- Some of these NSAID medicines are sold in lower doses without a prescription (over-the-counter). Talk to your healthcare provider before using over-the-counter NSAIDs for more than 10 days.

NSAID medicines that need a prescription

Generic Name	Tradename
Celecoxib	Celebrex
Diclofenac	Cataflam, Voltaren, Arthrotec (combined with misoprostol)
Diflunisal	Dolobid
Etodolac	Lodine, Lodine XL
Fenoprofen	Nalfon, Nalfon 200
Flurbiprofen	Ansaid
Ibuprofen	Motrin, Tab-Profen, Vicoprofen* (combined with hydrocodone), Combunox (combined with oxycodone)
Indomethacin	Indocin, Indocin SR, Indo-Lemmon, Indomethagan
Ketoprofen	Oruvail
Ketorolac	Toradol
Mefenamic Acid	Ponstel
Meloxicam	Mobic
Nabumetone	Relafen
Naproxen	Naprosyn, Anaprox, Anaprox DS, EC-Naproxyn, Naprelan, Naprapac (copackaged with lansoprazole)
Oxaprozin	Daypro
Piroxicam	Feldene
Sulindac	Clinoril
Tolmetin	Tolectin, Tolectin DS, Tolectin 600

* Vicoprofen contains the same dose of ibuprofen as over-the-counter (OTC) NSAIDs, and is usually used for less than 10 days to treat pain. The OTC NSAID label warns that long term continuous use may increase the risk of heart attack or stroke.

This Medication Guide has been approved by the U.S. Food and Drug Administration.

Greek God Invents FREE Love

Inspired by a mythological romance, this stunning 170-carat amethyst bead necklace is yours for the taking!

She was Amethyst, a maiden devoted to virtue. He was Dionysus, the notorious Greek god of intoxication and revelry. He loved her, but she wanted to wait for someone more suitable. He was a god, used to getting what he wanted. The chase was on. But once Diana saw that Amethyst was serious about keeping her heart pure, the goddess transformed her into a statue of perfect stone. Dionysus stopped partying for a moment and wept. He spilled his wine and infused the statue with the rich violet color we now know as amethyst.

It's not what you would call a happy ending. Luckily we discovered that something good came from their ill-fated romance. Specifically, this spectacular 170-Carat ***Amethyst Maiden Necklace***. And the incredible price may just have you shedding tears of joy. For a limited time, you can get 170 carats of polished purple gems valued at $249...absolutely FREE (you pay only for basic shipping and processing).

Drape yourself in purple perfection. Each rounded bead retains its own unique shape and just the right amount of translucence to let the light ignite the velvety, violet hues. Each gem is hand set on double-knotted jeweler's thread. The entire length secures with a .925 sterling silver lobster clasp layered in gold. The 18" necklace (with 2" extender) hangs with the same weight and elegance as similar strands that sell for hundreds more.

Extremely limited offer. The good news is that right now, you can get the 170-Carat ***Amethyst Maiden Necklace*** for **FREE** (you pay only the standard $24.^{95}$ shipping and processing fee). **We'll also include a $20 Stauer Gift Coupon with your delivery**, good towards your very next purchase. If you're interested in getting 170 carats of genuine amethyst for nothing...we recommend you reserve your necklace now. Because as Dionysus knows all too well, the party can't last forever. **This offer is strictly limited to one FREE necklace per shipping address.**

Amethyst Necklace (170 ctw)—~~$249~~

Your Cost—**FREE** — pay only $24.95 shipping & processing.

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VISIONS



Afghanistan
On drought-pocked earth near Marjah, in the restive Helmand Province, a lone shepherd leads his sheep through a mud wall's gap. Scenes of pastoral grace persist in this agriculturally intensive country, despite strife, insecurity, and dire food shortages.

PHOTO: KEVIN FRAYER, AP IMAGES





Tajikistan
Long hair flowing in the Pamir mountain air, two sisters prepare to bathe in a pond near Rushan. Several major ranges radiate from this region, providing water—some of it diverted for irrigation and a growing populace—to much of Central Asia.

PHOTO: CAROLYN DRAKE, PANOS PICTURES





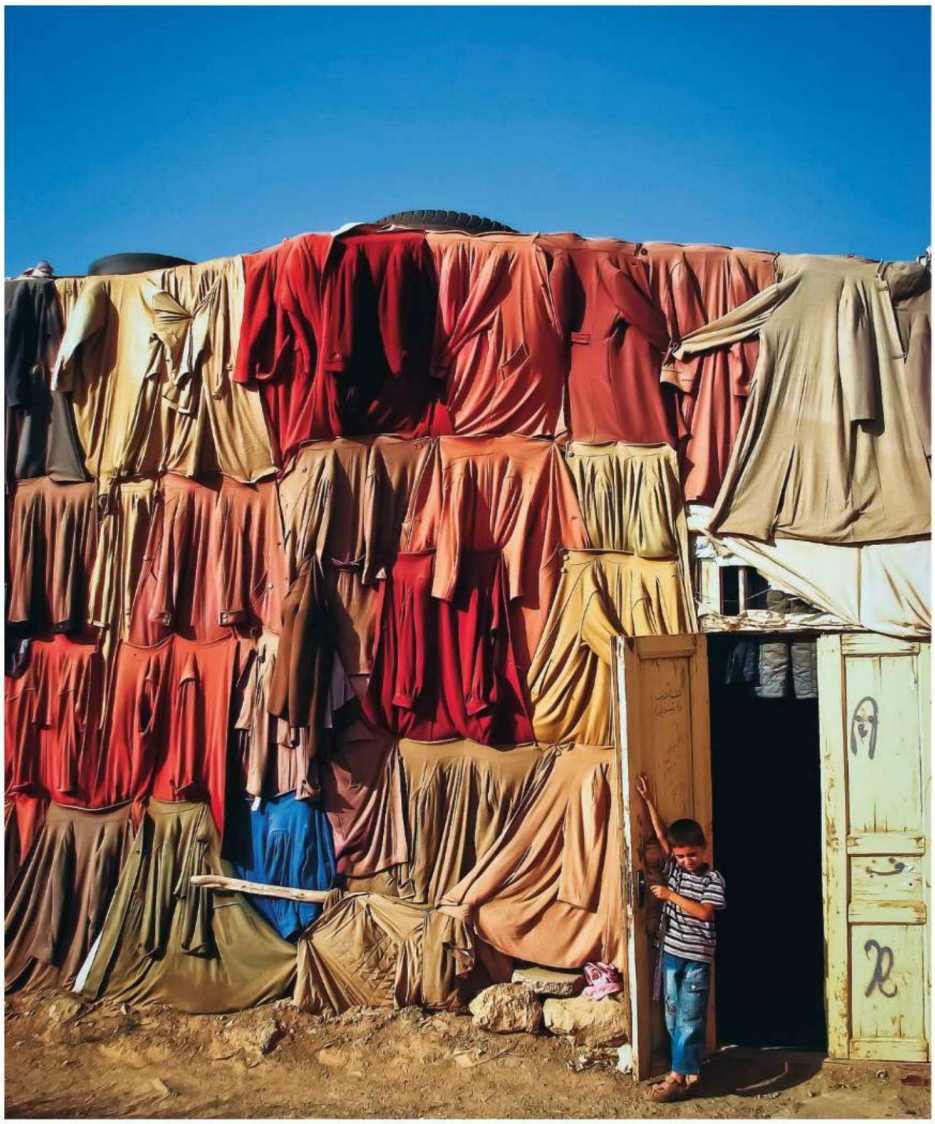
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France
On a bright summer morning a captive-bred male harvest mouse perches acrobatically in an Alsace wheat field. This species—the smallest European rodent—boasts a prehensile tail and builds a round nest that resembles a bird's.

PHOTO: J. L. KLEIN AND M. L. HUBERT, BIOSPHOTO

This page features two photographs: one chosen by our editors and one chosen by our readers via online voting. For more information, go to *ngm.com/yourshot.*



EDITORS' CHOICE

Sajad Jamali
Tehran, Iran

Strolling in the Kurdish city of Mahabad, Jamali, 29, was drawn to this "great wall of color"—a makeshift store where used clothing from Europe is displayed and sold. As a young boy stands in the doorway, coats and other garments beckon customers—and photographers.



READERS' CHOICE

N. Vijayaraghavan
Grenoble, France

When Vijayaraghavan, 31, descended from the top of Paris's Eiffel Tower on a sunny spring day, he saw a cluster of people on the ground below. "Each shadow was different," he says, "and seemed to be telling its own unique story."

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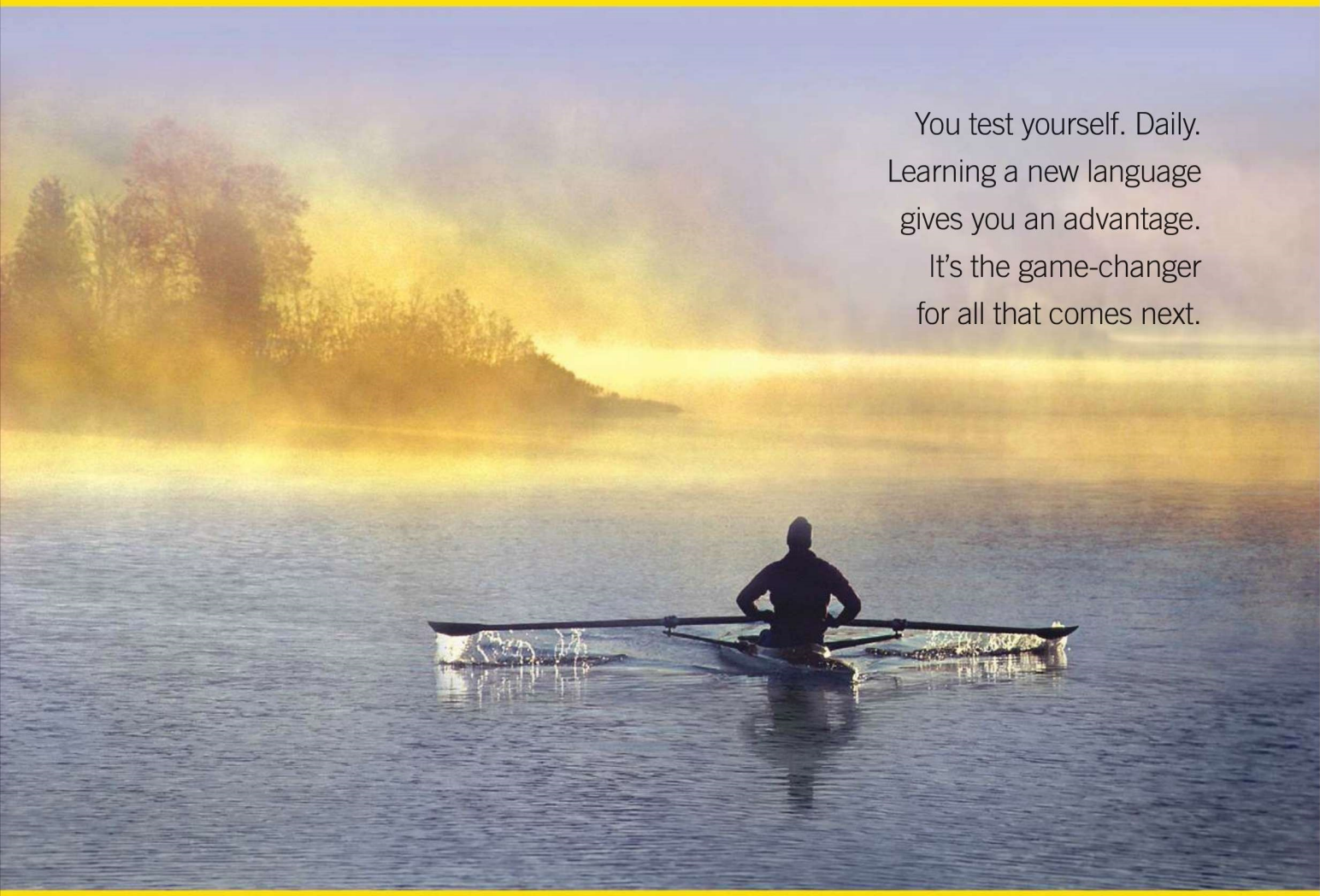
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NOW

SKYCAST

Overhead this month in parts of the world

February 25

The crescent moon and Venus—the sky's brightest planet—appear in proximity tonight.



In 2011 a replica horn was stolen from this rhino in England's Natural History Museum at Tring.

Horn Heists

Until recently, stuffed rhinoceroses stood intact in Europe's museum halls, a heritage of hundred-year-old hunting expeditions. But then the black market value of rhino horns rose, fueled in part by Asian rumors that they cure cancer. Now, with horns said to be fetching as much per ounce as gold or cocaine, postmortem poachers are making the imperiled species an imperiled specimen as well.

In the first eight months of 2011 alone, thieves broke into multiple museums, an auction house, a zoo exhibit, and a Czech castle (map). In some cases they sawed off the horns; in others they made off with whole 200-pound mounted heads. Museums are being advised to hide their rhinos or install replicas. Christian Michel of Belgium's Liège University Aquarium-Muséum says a sign now informs visitors that the rhinoceros there is fake "due to human stupidity." *—Kelly Enright*



NEXT MONTH Read more about the plight of rhinos in our March 2012 issue.



Words culled from 19 million dating profiles speak to who we are and what we love.

United Dates of America

Governments like to look at statistics—incomes, jobs, ages—to size up a nation. But that's not really *us,* says New York City artist and computer programmer R. Luke DuBois, who asks, "What if, instead, we looked at what people do on a Saturday night?" To find out, he jumped online and analyzed profiles from 21 dating websites, searching every U.S. zip code. In places where words appeared more often than anywhere else, he pulled out the terms and mapped them. The result, some of which is illustrated here, is "a romantic riff on the government census," he says.

Certain matches appear fated ("acting" and Los Angeles, "wet" and a Seattle suburb), others less so ("marshmallow" and Oskaloosa, Iowa). As with all relationships, some even get caught up in mixed messages. "Tryst," for instance, may evoke clandestine affairs in Washington, D.C., but it's also the name of a popular neighborhood café. *—Catherine Zuckerman*

THE LIST

TERMS OF ENDEARMENT "My angel," Beethoven wrote in letters to his mysterious Immortal Beloved. The object of the composer's affection may be unknown, but one thing is certain: Pet names have endured the test of time, and translate love in any language. —CZ

English	Afrikaans
honey	*bokkie*
	little buck



French	Turkish	Persian	Swedish	Thai	Russian	Quechua
mon chou	*sultanım*	*jigar*	*sötnos*	*jum-mum*	*radost moya*	*urpi sunqu*
my cabbage or my cream puff	my sultan	liver	sweet snout	roly-poly	my joy	dove heart

KAITLIN M. YARNALL, NGM STAFF. ART: MARC JOHNS. SOURCE: R. LUKE DuBOIS

NATIONAL GEOGRAPHIC

Inspire Future Generations



Grace Cleere included National Geographic in her estate plans.

A communications expert for the government, Grace Cleere recently named National Geographic as a beneficiary in her will. "I included a bequest intention to National Geographic because I believe in everything the organization represents," says Cleere. "If we don't understand our world, we are bound to mistreat it. And if we are not curious about all living things on our planet, we are bound to lose them through thoughtlessness and indifference. National Geographic shines a spotlight on the critical issues of the day and proposes innovative solutions that are grounded in science. I feel good about my legacy knowing that National Geographic will leverage my gift so it can have the greatest impact."

It is easy to include National Geographic in your will. For more information about how to include National Geographic in your estate plans, or to let us know that you have already done so, please contact the Office of Estate Planning.

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Photo: Adam Buchanan



What Stauer Clients Are Saying About Our Hybrid Watches

★★★★★

"Great watch... an impressive piece straight out of the box."
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No More Mr. Nice Watch

Forget sleek and subtle, the Stauer Colossus Hybrid is one tough timepiece.

Never underestimate your competition. Just ask Demetrius, the unfortunate Greek general who set out to conquer Rhodes in 305 BC. He assumed that a massive force of 40,000 men, a fleet of Aegean pirates and an arsenal of wall-smashing war machines would be enough to crush the tiny Greek island. He was wrong. The Rhodians were tougher than he thought. And so is this watch. If you've always believed that the biggest, baddest watches had to cost big, bad money, the $79 Stauer ***Colossus Hybrid Chronograph*** is here to change your mind.

A monument to toughness. The people of Rhodes were ready for Demetrius and repelled his attack. To celebrate, they built the Colossus of Rhodes, a 107-foot bronze and iron giant that towered over the harbor like a ten-story trophy. It warned future invaders that "Rhodes is tougher than you think." You give the same message when you wear the Stauer ***Colossus***.

The timepiece that works twice as hard. In designing the ***Colossus Hybrid Chronograph***, our instructions to the watchmaker were clear: build it as tough as a battleship and fill it full of surprises. Make it a hybrid, because it should work twice as hard as a regular watch. And make it look like a million bucks, because when you put it on, you should get excited about rolling up your sleeves. Mission accomplished.

A toolbox on your wrist. It will keep you on schedule, but the ***Colossus Hybrid*** is about much more than time. The imposing case features a rotating gunmetal bezel that frames the silver, black and yellow face. You'll find a battalion of digital displays on the dial arranged behind a pair of luminescent hands and a bold yellow second hand. Powered by a precise quartz movement, the watch is doubly accurate in analog and digital mode. And it's packed with plenty of handy extras including a bright green EL back-light for enhanced nighttime visibility, a tachymeter along the outer dial and a full complement of alarms and split-second countdown timers. The ***Colossus Hybrid*** secures with a folded steel bracelet that highlights a row of striking dark center links. It's a rugged watch that's more than ready for your daily grind.

Your Satisfaction is Guaranteed. Wear the Stauer ***Colossus Hybrid*** for 30 days and if you are not 100% thrilled with your purchase, return it for a full refund of your purchase price. But once you get a taste of more watch for less money, it's likely you'll be back for more... and we'll be waiting.

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Mastodon Mystery

Last spring scientists recovered a vast trove of Ice Age fossils, spied by a sharp-eyed bulldozer driver at a reservoir near Snowmass Village, Colorado. Many of the bones—including this mandible (right)—belonged to mastodons.

More massive than today's African elephant but shorter than their mammoth cousins, mastodons browsed here beside what was once a lake in a lush forest. But a riddle remains: Why did so many of them die in this particular spot?

Kirk Johnson of the Denver Museum of Nature & Science is investigating a macabre scenario in which periodic earthquakes caused the soil to swiftly liquefy then harden, repeatedly trapping entire mastodon families. Unable to move, the mighty tusked beasts slowly starved to death. "If we're right," says Johnson, "the lake was an Ice Age death trap." *—Evan Hadingham*

5,569 Ice Age fossils have been found at a Colorado site, including



105	73	49	34	23
Loose teeth	Tusks	Mandibles	Skulls	Pelvises

PHOTO: CHRIS SCHNEIDER. ART: HANNAH TAK, NGM STAFF



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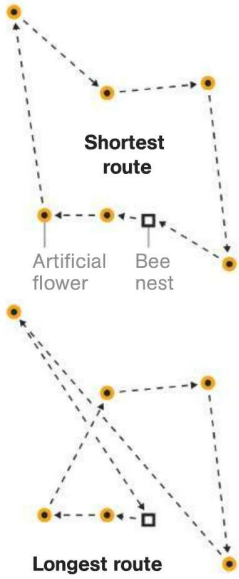


Bumblebees travel up to five miles per foraging trip, so optimizing routes among flowers helps conserve energy.

Bumblebee Math

The flight of the bumblebee—even when not set to music—may seem frenetic and random as the workers forage for pollen and nectar to carry home. But researchers at Queen Mary, University of London discovered there's choreography in the flower bed. Each bee has a brain the size of a grass seed, but the insects are able to harvest efficiently by solving one of math's great puzzles: the traveling salesman problem.

The challenge is to find the shortest way to visit each flower once before returning to the nest. Computers must resort to laborious calculations, measuring each possible route. The bees studied, *Bombus terrestris,* and perhaps other species use spatial memory, rapidly refining routes through trial and error. (Hint: Moving to the next nearest flower isn't the answer.) Scientists know why the bees do it—flying is exhausting. Now they're trying to figure out *how* the insects do it. Learning what dictates their decisions could yield insights that improve our transportation and communication networks. To the bees, it's just a matter of good orchestration. *—Gretchen Parker*



FAST LEARNERS *In lab trials, bees found the shortest route connecting six flowers without trying all the possible paths. Each bee was tested 80 times and used the shortest route more frequently over time.*



PHOTO: ANDRE SKONIECZNY, IMAGEBROKER/ALAMY. GRAPHICS: LAWSON PARKER, NGM STAFF. SOURCE: NIGEL RAINE, ROYAL HOLLOWAY, UNIVERSITY OF LONDON

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Excitement swept through my body

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- Have more energy
- Appear taller
- Jump higher, walk and run faster
- Have instant comfort
- Cool your feet & reduce foot odor
- Elevate your performance

I put them on and all I could say was, "WOW!" In minutes I was out the door. I was invincible; tireless in my new Gravity Defyer shoes. It was as if my legs had been replaced with super-powered bionics. What the doctor promised was all correct. No more knee pain. I started to lose weight. At last, I was pain free and filled with energy! I was back in the game. Gravity had no power over me!

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So, my friend, get back on your feet like I did. Try Gravity Defyer for yourself. You have nothing to lose but your pain.



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Reduce fatigue. Be more active

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NEXT

AIDS Illumination

Glow, cat, glow! That light helps researchers see if you might be capable of resisting feline immunodeficiency virus—a development that could one day point the way toward protecting humans against HIV/AIDS.

FIV causes AIDS in cats much as HIV does in people, by decimating infection-fighting T cells. So last year a team led by the Mayo Clinic's Eric Poeschla inserted a rhesus macaque gene—producer of an antiviral protein—into unfertilized feline eggs. To monitor the gene transference under microscopes and certain lights, Poeschla added a luminescent protein from a jellyfish. The next-generation result: glow-in-the-dark kittens that produce the antiviral protein themselves. Soon he'll see if the modified cats are truly FIV immune.

Paula Cannon, a University of Southern California gene therapist, says the illuminating work is "a vital step" in genome-based AIDS research—for the health of humans and cats alike. *—Jeremy Berlin*



Glowing in the dark thanks to a jellyfish's green fluorescent protein, this cat has a monkey gene that may help it resist the feline form of AIDS.

PHOTO: MARK THIESSEN, NGM STAFF

Landing on Mars



BLASTOFF

An Atlas V rocket sends the spacecraft carrying Curiosity on its 350-million-mile journey to Mars.

3... 2... 1...



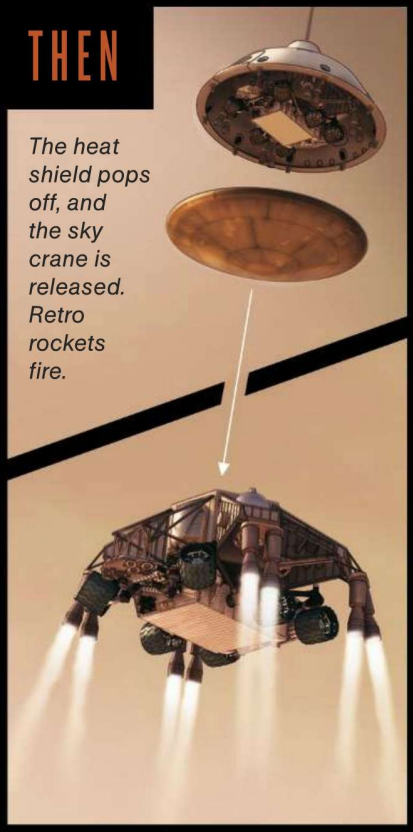
Moving at 13,000 miles an hour, the aeroshell enters the Martian atmosphere

FWOOMP!

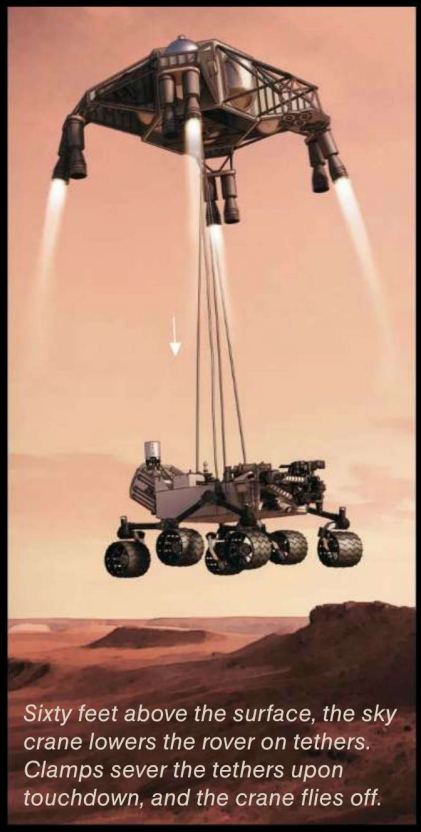


The parachute deploys, slowing the descent.

THEN



The heat shield pops off, and the sky crane is released. Retro rockets fire.



Sixty feet above the surface, the sky crane lowers the rover on tethers. Clamps sever the tethers upon touchdown, and the crane flies off.



CURIOSITY, A NEW ROVING ROBOT, is due to land on Mars in August, and this time NASA has left the air bags at home. The rover's predecessors, Spirit and Opportunity, bounced onto the red planet in 2004 encased in cushioning. Packed with more science gadgets, the latest visitor is bigger and five times as heavy, so engineers needed a way to safely deliver a much larger package. Enter the sky crane, a new approach for NASA that—if successful—could become standard for landing big bots on

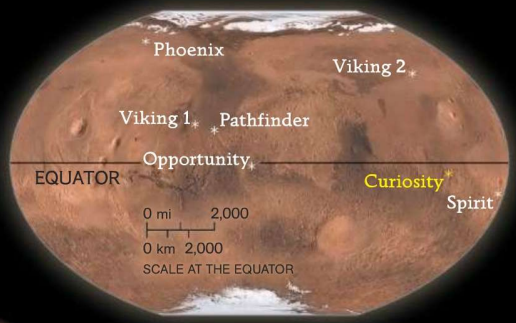


NEXT

Upon reaching Mars, the cruise stage separates, and the aeroshell begins its descent.

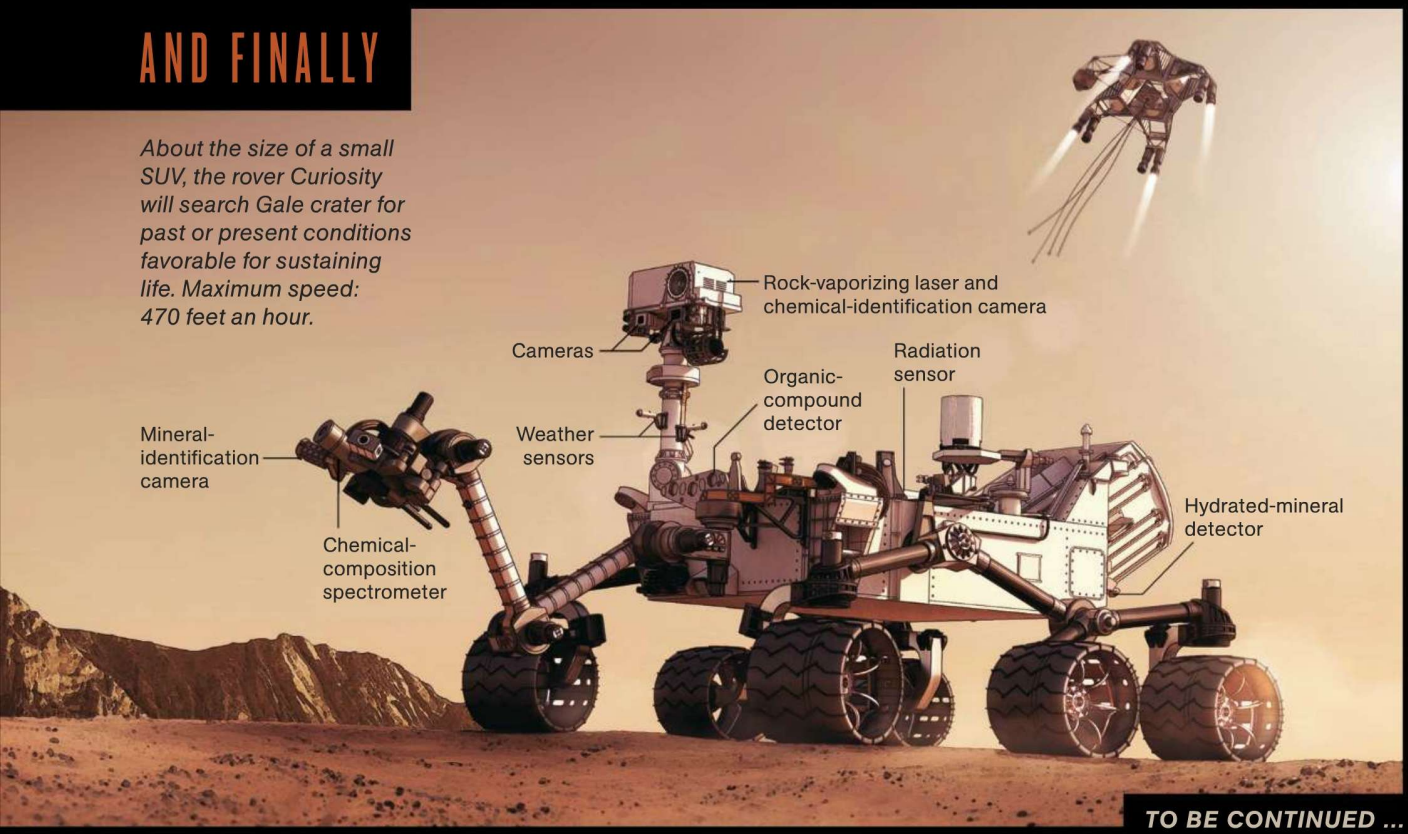

Cruise stage


Aeroshell



AND FINALLY

About the size of a small SUV, the rover Curiosity will search Gale crater for past or present conditions favorable for sustaining life. Maximum speed: 470 feet an hour.



TO BE CONTINUED ...

other worlds. The crane's retro rockets allow for a gentle landing, and it will stay tethered to Curiosity until the rover's wheels are on stable ground. If all goes as planned, Curiosity will set down next to a three-mile-high mountain in Gale crater with rock layers rich in clays and sulfates, minerals known to form only in the presence of liquid water, a key ingredient for life. Scientists hope these layers will yield a story of a planet with conditions that were—or are—hospitable to life. *—Victoria Jaggard*

OLIVER UBERTI, NGM STAFF. ART: NICK KALOTERAKIS. NG MAPS. SOURCE: NASA

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— Stauer Client, Oklahoma City, OK

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50 carat genuine emerald enlarged to show details.

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Mineral Class	Beryl		
Color	Deep Green		
Hardness	7.5 on the MOHs Scale		
Cut	Faceted	Birthstone	May
Refractive Index	1.577-1.583		

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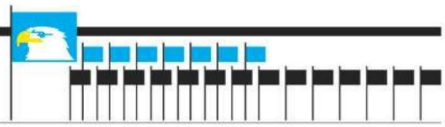
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Of the 193 states recognized by the UN, 22 have flags with animals. Eight depict eagles.



Moving Toward Integration

Brown University sociologist John Logan has pored over the melting pot in microcosm for 40 years. Last year he sifted through U.S. census data from 1980 to 2010 and identified 20 traditionally multiethnic metropolitan centers, including Los Angeles, Newark, and Houston. He discovered in the stats that communities with a high level of integration of four key groups are on the rise.

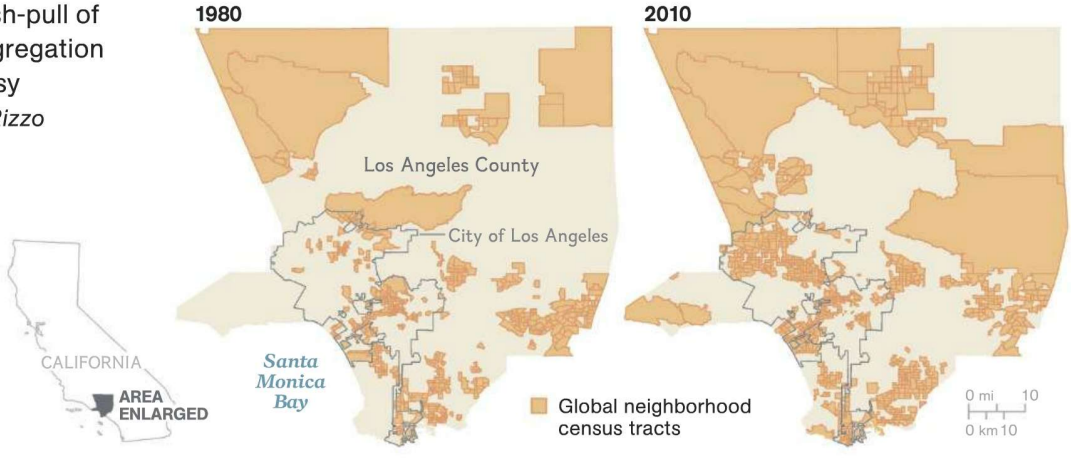
These "global neighborhoods" start out as predominantly white communities that Hispanics and Asians move into, followed by blacks. What surprised Logan was that this specific pattern of integration showed much greater stability than expected. More than 60 percent of the global neighborhoods remained mixed after 30 years, he notes. These areas, based on census tracts, are on average nearly half white and about a quarter Hispanic, with the rest evenly split between blacks and Asians.

On the flip side, minority-only tracts have proved increasingly entrenched, and white flight into the suburbs continues. Altogether, the push-pull of integration and segregation makes for an uneasy balance. *—Johnna Rizzo*



Gauging Head Injuries

Since 2000 some 220,000 U.S. troops have suffered traumatic brain injuries, often from exposure to explosions. To fathom—and treat—such wounds, blast data are key. So last year the U.S. military and private-sector partners developed and deployed devices that assess explosion severity. In field testing, soldiers wear the watch-size dosimeter on their chests (above), shoulders, and heads. The gauges measure pressure and acceleration, letting medics press a button and evaluate risk in color-coded, traffic light style: red for serious, yellow for moderate, green for insignificant. *—Jeremy Berlin*



In greater Los Angeles, "global neighborhoods" of whites, blacks, Hispanics, and Asians are expanding.

PHOTO: DEFENSE ADVANCED RESEARCH PROJECTS AGENCY. NGM MAPS. SOURCES: JOHN R. LOGAN, BROWN UNIVERSITY; CHARLES ZHANG, TEXAS A&M UNIVERSITY. GRAPHIC: ÁLVARO VALIÑO. SOURCE: UNITED NATIONS





MIX MATCH MORPH

HOW TO BUILD A DOG

SIMPLE GENETIC TWEAKS DECIDE THE DIFFERENCE BETWEEN A GREAT DANE (LEFT) AND A BRUSSELS GRIFFON (ABOVE).

Scientists have found the secret recipe behind the spectacular variety of dog shapes and sizes, and it could help unravel the complexity of human genetic disease.


FRENCH BULLDOG 21
AUSTRALIAN SHEPHERD 26
BLOODHOUND 43
GREAT PYRENEES 71
CHINESE SHAR-PEI 50
DOBERMAN PINSCHER 14
ALL DOGS FROM THE 2011 WESTMINSTER DOG SHOW. AMERICAN KENNEL CLUB 2010 POPULARITY RANKING LISTED AFTER NAME OF BREED
DOBERMAN PINSCHER 14
PEMBROKE WELSH CORGI 27
CARDIGAN WELSH CORGI 84
IRISH SETTER 77
DOGUE DE BORDEAUX 68
POODLE 9
BLACK RUSSIAN TERRIER 135
ENGLISH SPRINGER SPANIEL 29
AFGHAN HOUND 86
AUSTRALIAN TERRIER 123
CHINESE CRESTED 57
CHESAPEAKE BAY RETRIEVER 48
YORKSHIRE TERRIER 3
PUG 24
BORDER COLLIE 47
BELGIAN MALINOIS 76
GERMAN SHORTHAIRED POINTER 16


GREATER SWISS MOUNTAIN DOG 88
DANDIE DINMONT TERRIER 164
POMERANIAN 15
PUG 24
AUSTRALIAN TERRIER 123
SAINT BERNARD 45
BLOODHOUND 43
GERMAN SHORTHAIRED POINTER 16
SUSSEX SPANIEL 155
MASTIFF 28
AUSTRALIAN SHEPHERD 26
SALUKI 115
TIBETAN MASTIFF 124
GREAT DANE 17
RHODESIAN RIDGEBACK 46
ICELANDIC SHEEPDOG 82
ENGLISH SETTER 101
IRISH SETTER 77
GORDON SETTER 98
ITALIAN GREYHOUND 67
BICHON FRISE 37
CHOW CHOW 65
DACHSHUND 8
DOGUE DE BORDEAUX 68
PAPILLON 35
LABRADOR RETRIEVER 1
AFGHAN HOUND 86



Along with the patchwork of breeds pictured on the previous pages, Manny, an Afghan hound (right), and Razbery, an English setter (left), represent the best of the best: entrants in the Westminster Kennel Club's 135th annual dog show. The centuries of breeding that produced such striking diversity also created isolated genetic populations that are helping scientists understand human diseases. "We're the people doing the genetics," says one researcher. "But breeders have done all the fieldwork."



BY EVAN RATLIFF · PHOTOGRAPHS BY ROBERT CLARK



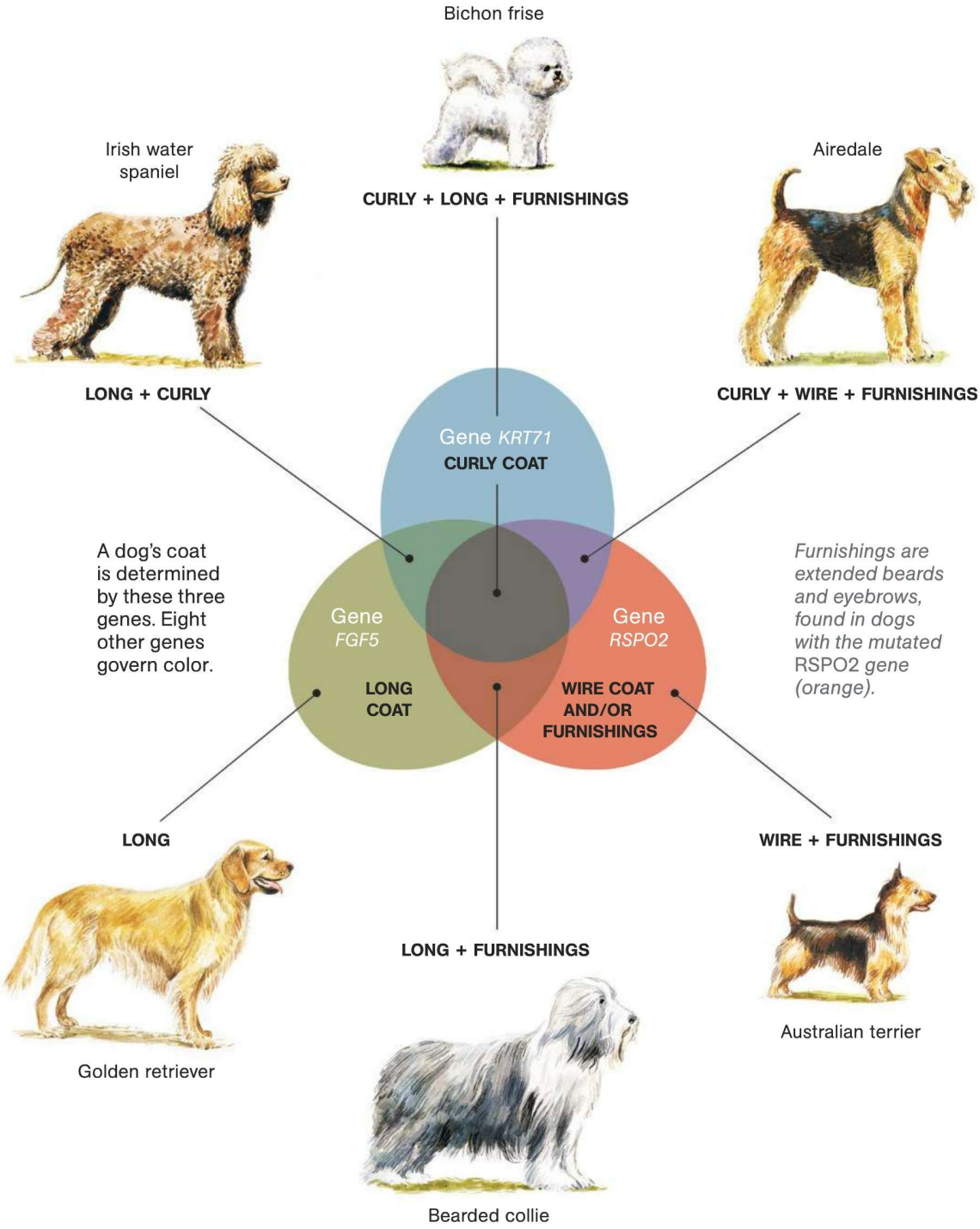
BICHON FRISE, 37TH ON THE AKC'S POPULARITY RANKING OF BREEDS

It's an unusually balmy mid-February afternoon in New York City, but the lobby of the Hotel Pennsylvania is teeming with fur coats.

The wearers are attendees of what is undoubtedly the world's elite canine mixer, one that takes place each year on the eve of the Westminster Kennel Club dog show. Tomorrow the nation's top dogs from 173 breeds will compete for glory across the street at Madison Square Garden. But today is more akin to a four-legged meet-and-greet, as owners shuffle through the check-in line at the competition's official lodgings. A basset hound aims a droopy eye across a luggage cart at a wired-up terrier. A pair of muscled Rhodesian ridgebacks, with matching leather leashes, pause for a brief hello with a fluffy Pyrenean shepherd. Outside the gift shop a Tibetan mastiff with paws the size of human hands goes nose to nose with a snuffling pug.

The variety on display in the hotel lobby—a dizzying array of body sizes, ear shapes, nose lengths, and barking habits—is what makes dog lovers such obstinate partisans. For reasons both practical and whimsical, man's best friend has been artificially evolved into the most diverse animal on the planet—a staggering achievement, given that most of the 350 to 400 dog breeds in existence have been around for only a couple hundred years. The breeders fast-forwarded the normal pace of evolution by combining traits from disparate dogs and accentuating them by breeding those offspring with the largest hints of the desired attributes. To create a dog well suited for cornering badgers, for instance, it is thought that German hunters in the 18th and 19th centuries brought together some combination of hounds—the basset, a native of France, being the likely suspect—and terriers, producing a new variation on the theme of dog with stubby legs and a rounded body that enabled it to chase its prey into the mouth of a burrow: hence the dachshund, or "badger dog" in German. (A rival, flimsier history of the breed has

Evan Ratliff wrote on the origins of domestication in the March 2011 issue. Brooklyn-based Robert Clark's last dog, a pit bull named Leo, now lives on a farm.



HAIR OF THE DOG Hundreds of genes interact to produce a physical trait in humans and most mammals. For dog traits, the magic number is usually three or fewer. The type of coat a dog wears depends on the three genes shown above. Mutations in these genes create a coat that's long, curly, wiry, or a combination. If none of the three genes are mutated, the dog will have the short, smooth coat of breeds like beagles and basset hounds—and the dog's ancestor, the gray wolf.

JOHN TOMANIO, NGM STAFF. DOG ILLUSTRATIONS: DAN WILLIAMS
SOURCE: ADAM BOYKO, CORNELL UNIVERSITY



Researchers have identified a single gene mutation that causes the “hairlessness” of dogs like Sugar, a Chinese crested (right). The eye-shielding curls of Charlotte, a black-haired puli (above), are produced by the interaction of three genes.





LIKE ITS ANCESTOR THE GRAY WOLF, THE BASENJI, ONE OF THE MOST ANCIENT BREEDS, DOESN'T BARK.

it dating back, in some form, to ancient Egypt.) Pliable skin served as a defense mechanism, allowing the dog to endure sharp-toothed bites without significant damage. A long and sturdy tail helped hunters to retrieve it from an animal's lair, badger in its mouth.

The breeders gave no thought, of course, to the fact that while coaxing such weird new dogs into existence, they were also tinkering with the genes that determine canine anatomy in the first place. Scientists since have assumed that underneath the morphological diversity of dogs lay an equivalent amount of genetic diversity. A recent explosion in canine genomic research, however, has led to a surprising, and opposite, conclusion: The vast mosaic of dog shapes, colors, and sizes is decided largely by changes in a mere handful of gene regions. The difference between the dachshund's diminutive body and the Rottweiler's massive one hangs on the sequence of a single gene. The disparity between the dachshund's stumpy legs—known officially as disproportionate dwarfism, or chondrodysplasia—and a greyhound's sleek ones is determined by another one.

The same holds true across every breed and almost every physical trait. In a project called CanMap, a collaboration among Cornell University, UCLA, and the National Institutes of Health, researchers gathered DNA from more than 900 dogs representing 80 breeds, as well as from wild canids such as gray wolves and coyotes. They found that body size, hair length, fur type, nose shape, ear positioning, coat color, and the other traits that together define a breed's appearance are controlled by somewhere in the neighborhood of 50 genetic switches. The difference between floppy and erect ears is determined by a single gene region in canine chromosome 10, or CFA10. The wrinkled skin of a Chinese shar-pei traces to another region, called HAS2. The patch of ridged fur on Rhodesian ridgebacks? That's from a change in CFA18. Flip a few switches, and your dachshund becomes a Doberman, at least in appearance. Flip again, and your Doberman is a Dalmatian.

"The story that is emerging," says Robert Wayne, a biologist at UCLA, "is that the diversity in domestic dogs derives from a small genetic tool kit."

Media reports about *the* gene for red hair, alcoholism, or breast cancer give the false impression that most traits are governed by just one or a few genes. In fact, the Tinkertoy genetics of dog morphology is a complete aberration. In nature, a physical trait or disease state is usually the product of a complex interaction of many genes, each one making a fractional contribution. Height in humans, for instance, is determined by the interaction of some 200 gene regions.

So why are dogs so different? The answer, the researchers say, lies in their unusual evolutionary history. Canines were the earliest domesticated animal, a process that started somewhere between 20,000 and 15,000 years ago, most likely when gray wolves began scavenging around human settlements. Dog experts differ on how active a role humans played in the next step, but eventually the relationship became a mutual one, as we began employing dogs for hunting, guarding, and companionship. Sheltered from the survival-of-the-fittest wilderness, those

FAMILY TIES

Analyzing the DNA of 85 dog breeds, scientists found that genetic similarities clustered them into four broad categories. The groupings reveal how breeders have recombined ancestral stock to create new breeds; a few still carry many wolflike genes. Researchers named the groups for a distinguishing trait in the breeds dominating the clusters, though not every dog necessarily shows that trait.

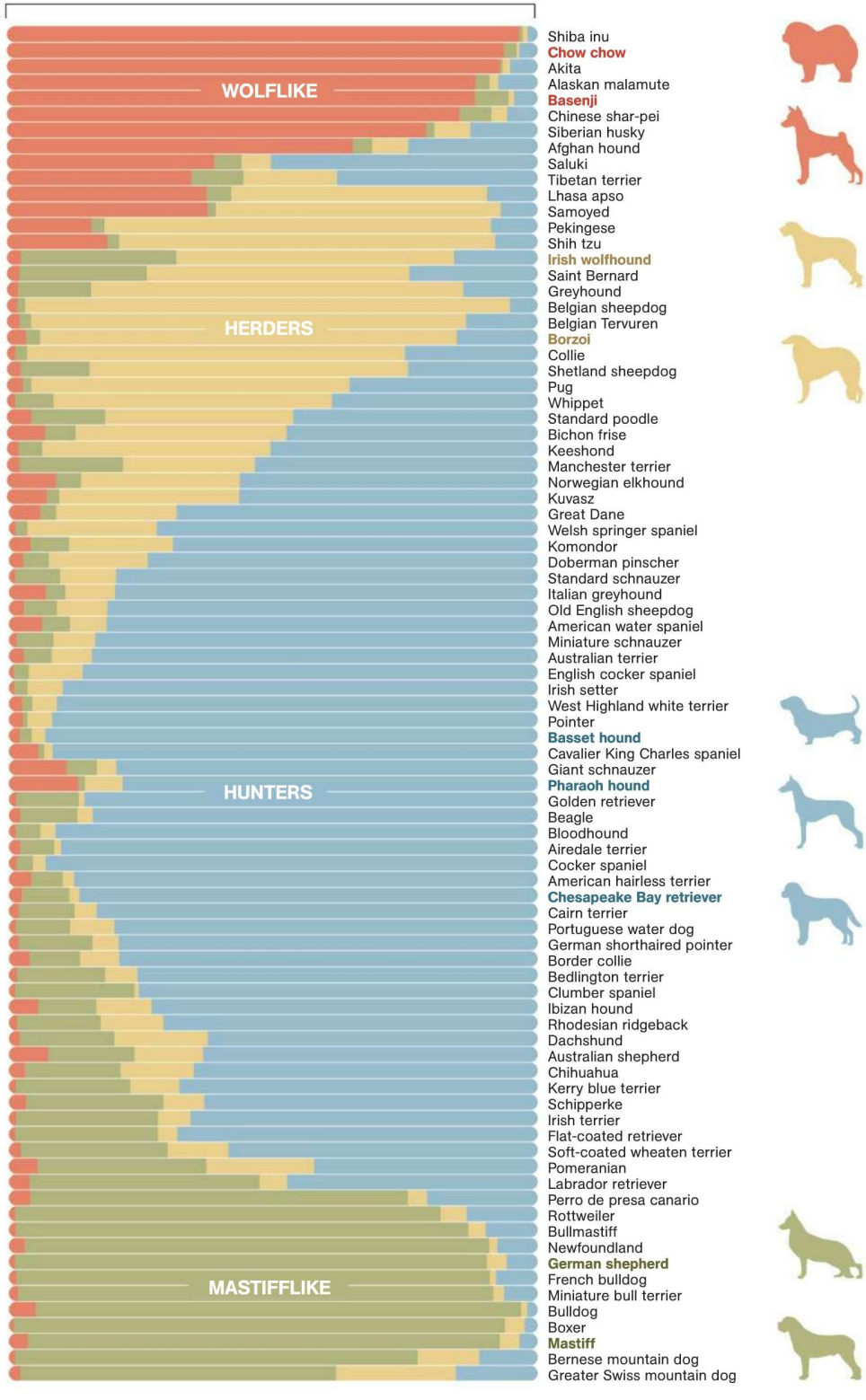
The length of the colored bars in a breed's genetic profile shows how much of the dog's DNA falls into each category.

WOLFLIKE
With roots in Asia, Africa, and the Middle East, these breeds are genetically closest to wolves, suggesting they are the oldest domesticated breeds.

HERDERS
Familiar herding breeds such as the Shetland sheepdog are joined by breeds never known for herding: the greyhound, pug, and borzoi. This suggests those breeds either were used in the creation of classic herding dogs or descended from them.

HUNTERS
Most in this group were developed in recent centuries as hunting dogs. While the pharaoh hound and Ibizan hound are said to descend from dogs seen on ancient Egyptian tombs, their placement here suggests they are re-creations bred to resemble ancient breeds.

MASTIFFLIKE
The German shepherd's appearance in this cluster, anchored by the mastiff, bulldog, and boxer, likely reflects its breeding as a military and police dog.



JOHN TOMANIO, LAWSON PARKER, NGM STAFF
SOURCE: HEIDI G. PARKER, NATIONAL HUMAN GENOME RESEARCH INSTITUTE, NATIONAL INSTITUTES OF HEALTH





Originally bred as guard dogs, Tibetan mastiffs like Midas, a Westminster finalist from Lubbock, Texas, can top 150 pounds. They are highly protective of their owners—an impulse that, along with most other dog behaviors, remains a genetic mystery.



Oakley, a pug (foreground), and Little Dude, a Saint Bernard, stand witness to the immense morphological diversity of their species. If humans varied as much in height, the smallest would be two feet tall and the tallest would measure some 31 feet.

semidomesticated dogs thrived even though they harbored deleterious genetic mutations—stumpy legs, for instance—that would have been weeded out in smaller wild populations.

Thousands of years later, breeders would seize on that diverse raw material when they began creating modern breeds. They tended to grab traits they desired from across multiple breeds—or tried to rapidly replicate mutations in the same one—in order to get the dog they wanted. They also favored novelty, since the more distinct a line of dogs appeared, the more likely it was to garner official recognition as a new breed. Such artificial selection tended to favor single genes with a large impact, allowing traits to be fixed more rapidly than groups of smaller-impact genes ever could.

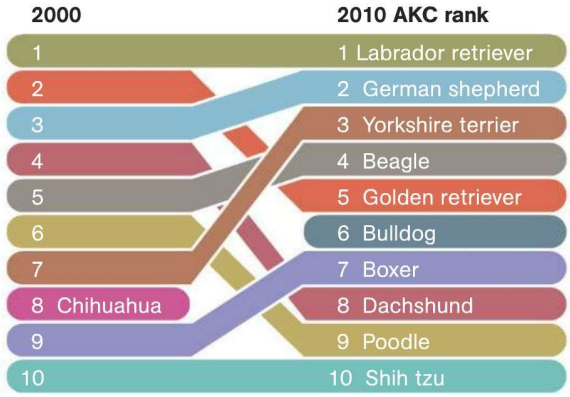
"It's kind of like when you set your remote control to control your TV, your stereo, and your cable," says Carlos Bustamante, a CanMap geneticist now at Stanford University. "You hit the on-off switch, and it does them all."

This revelation has implications the scientists are just beginning to unravel—most important, for the understanding of genetic disorders in humans. Already, more than a hundred dog diseases have been mapped to mutations in particular genes, many of them with human counterparts. Those diseases may have a whole array of mutations leading to a risk of disease in dogs, as they do in us. But because dogs have been genetically segregated into breeds developed from just a few original individuals, each breed has a much smaller set of errant genes—often only one or two—underlying the disease. For instance, Cornell researchers studying the degenerative eye disease retinitis pigmentosa—shared by humans and dogs—found 20 different canine genes causing the disorder. But a different gene was the culprit in schnauzers than in poodles, giving researchers some specific leads for where to start looking in humans. Meanwhile a recent study of a rare type of epilepsy in dachshunds found what appears to be a unique genetic signature, which could shed new light on the disorder in us as well.

In short, while the Victorian breeders were crafting dogs to suit their tastes, they were also creating genetically isolated populations, little knowing how useful they might be to scientists in the future. The possibilities are especially abundant for cancer, certain types of which can show up as often as 60 percent of the time in some dog breeds but only once in every 10,000 humans.

"We are the people who are doing the genetics," says Elaine Ostrander, who studies dog evolution and disease at the National Human Genome Research Institute at NIH. "But breeders are the people who have done all the fieldwork."

One category of trait that has so far proved resistant to the CanMap analysis is behavior. Only a single mutant behavioral gene has been identified to date: the dog version of the gene for obsessive-compulsive disorder in humans, which can cause Doberman pinschers to obsessively suck on their fur to the point of bleeding. More common characteristics such as loyalty, tenaciousness, or the instinct to herd clearly have genetic underpinnings. But they can also be affected by factors ranging from a dog's nutrition to the presence of children in the house, making them difficult to quantify rigorously enough to study. Nevertheless, "we've probably got as good a shot, if not better, of understanding behavior in dogs over other animals," says Stanford's Bustamante. After all, he points out, there are millions of dog lovers out there willing and eager to help with the fieldwork. □



TOP DOGS The most popular breeds in 2000 and 2010 by American Kennel Club registrations

NGM ART
SOURCE: AMERICAN KENNEL CLUB



For most of their evolutionary history, all dogs resembled these semiwild village dogs living among the Batammariba in Togo, West Africa.

Dog breeds were created by human beings. The village dog created itself.

THE FOREVER DOG

By Evan Ratliff

LABRADORS MAY BE the most popular breed of dog, but the most populous kind is no breed at all. That distinction goes to the humble village dog scratching out a semiwild living in and around human settlements.

While a postdoc at Cornell University a few years ago, Adam Boyko became curious about the little-studied village vagrants. Though dogs were first domesticated 20,000 to 15,000 years ago, most breeds go back only a few hundred years. Perhaps village dog DNA might shed light on the long, early history of domestication, when canines were hanging around humans yet not under our domain. But how to get samples?

As it happened, around the same time Boyko's brother Ryan had married, and he and wife Corin were looking for a cheap honeymoon off the beaten track. The three Boykos decided to merge their two quests. Adam—now at Cornell's College of Veterinary Medicine—obtained a grant, then enlisted Ryan and Corin to spend their honeymoon traveling around Egypt, Uganda, and Namibia, befriending villagers and local vets. They collected DNA from more than 300 village dogs.

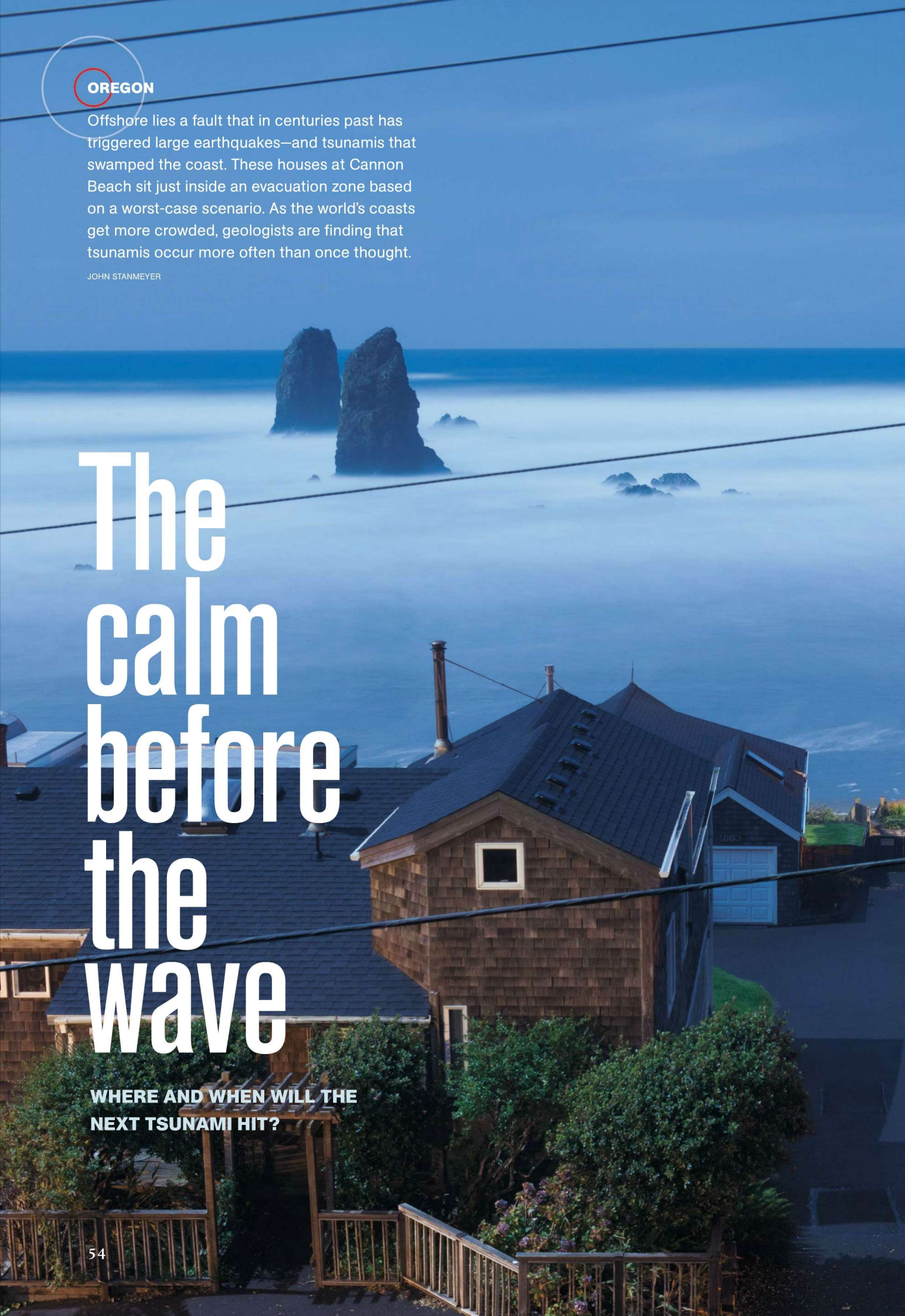
When the samples were analyzed, most of the village dogs turned out to be as closely related to wolves as they were to fully domesticated dogs. Rather than being mixed-breed mutts that had gone feral in historical times, the village dogs had been eking out an existence on the human fringe for millennia. Their genomes thus reflected a state of early domestication, before artificial selection and inbreeding directed by humans had taken over. "When you are looking at village dogs," Adam Boyko says, "you have something more akin to natural selection, albeit in an environment that's managed by humans."

Unexpectedly, the study also helped to challenge the reigning view on the place where dogs first appeared. Fossil evidence had already pinned the transition from wolf to dog somewhere in Europe or Asia, and a 2002 study had shown that East Asian village dogs were more genetically diverse—an indication that wolves had first been domesticated in East Asia. But the Boykos' 2009 work found that the African village dogs were just as diverse as the East Asian ones. Some also carried a genetic signature shared with Middle Eastern gray wolves, supporting research by Robert Wayne and Bridgett vonHoldt of UCLA that points to the Middle East as the likely cradle of dogs.

The Boykos continue to expand their sample collection, with another expedition planned for Africa. And they've also begun using the same techniques to solve a related mystery: the strange disappearance of native dogs in South America. We know from the historical record that Native Americans had dogs. But previous population surveys in the Americas turned up only dogs with European heritage. "How do you ship so many dogs across the world that they completely replace the native dogs?" Boyko wonders, suspecting that in fact there may still be village dogs with native DNA in the remotest areas of the continent. So in August the three Boykos packed their bags and headed into the jungles of Peru, searching for the lost American dog. □

Society Grant Ongoing fieldwork on the native American dog DNA is funded in part by your National Geographic Society membership.

ALIDA LATHAM, DANITA DELIMONT



OREGON

Offshore lies a fault that in centuries past has triggered large earthquakes—and tsunamis that swamped the coast. These houses at Cannon Beach sit just inside an evacuation zone based on a worst-case scenario. As the world's coasts get more crowded, geologists are finding that tsunamis occur more often than once thought.

JOHN STANMEYER

The calm before the wave

WHERE AND WHEN WILL THE NEXT TSUNAMI HIT?







JAPAN

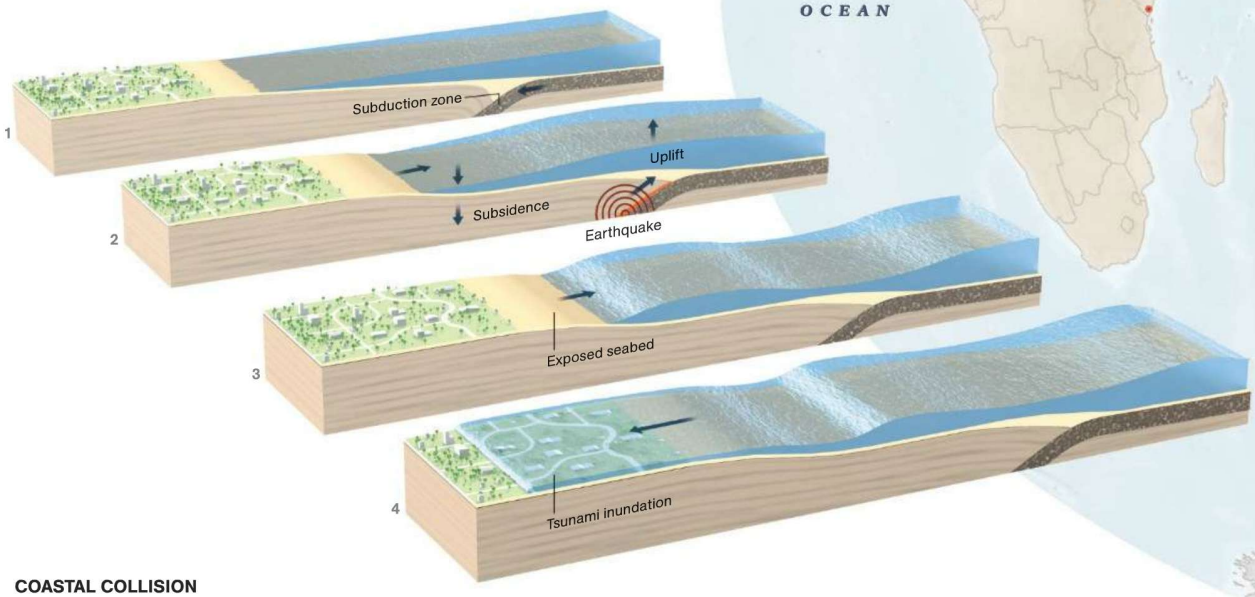
More than 1,500 people died last March in Rikuzentakata, one of several towns eradicated by the tsunami. “As the buildings were destroyed, black, dusty smoke was thrown up,” a survivor told an Al Jazeera reporter. “Then the tsunami swallowed up the smoke.”

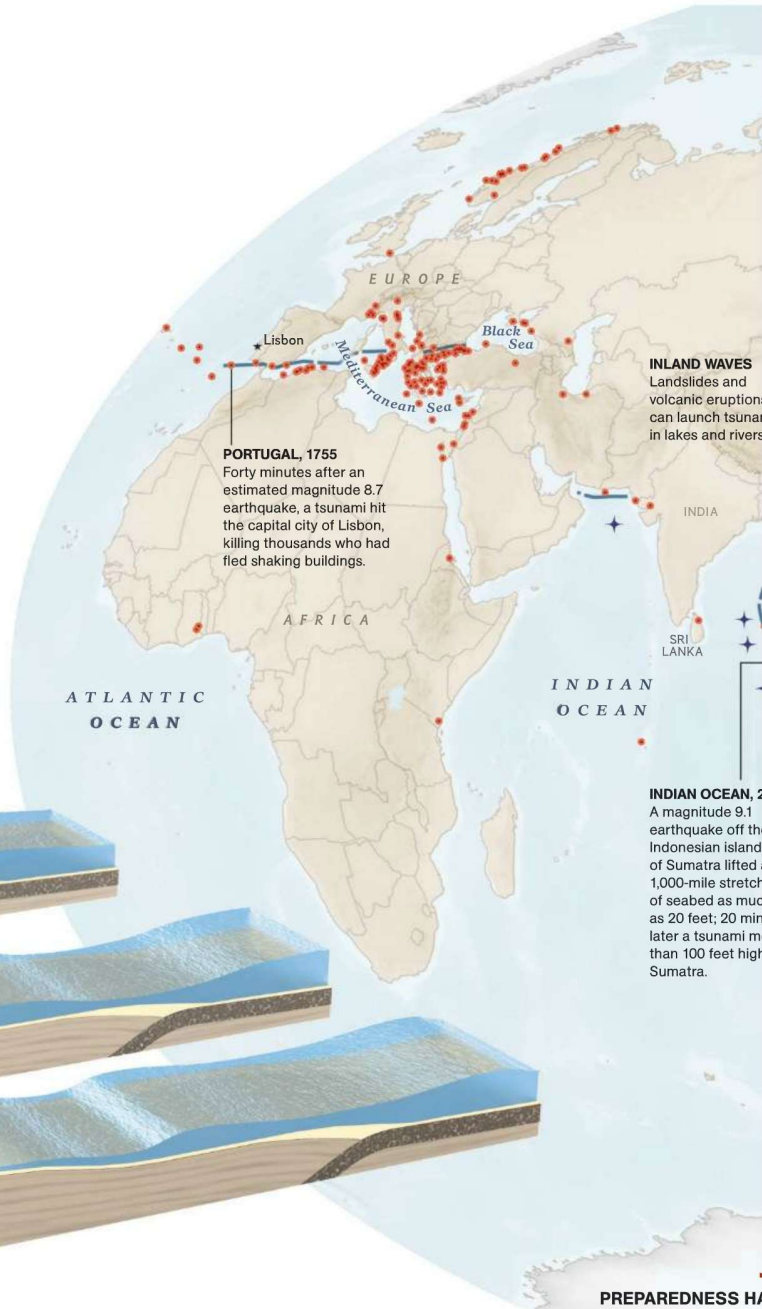
TAMON SUZUKI

Eye on tsunamis

Tsunamis aren't moon-driven tides or wind-driven waves at the sea surface. They're caused by violent movements of rock—seafloor earthquakes usually—that can put a whole ocean in motion. Since the first one on record, along Syria's coast in about 2000 B.C., a few thousand tsunamis have collectively killed more than 500,000 people. Nearly half those deaths occurred in a single catastrophe in the Indian Ocean in 2004; as coastal populations have boomed, tsunamis have grown more lethal. Their Japanese name—it means "harbor wave"—is perhaps a bit too quiet.

Most large tsunamis arise around the rim of the Pacific and Indian Oceans, along seafloor faults called subduction zones, where colliding tectonic plates trigger large earthquakes. Waves spread in opposite directions from the fault. Within minutes the first waves crash onto nearby land, as in Japan in 2011; within hours they cross the ocean. Even thousands of miles away, a harbor may not be safe.





PORTUGAL, 1755
Forty minutes after an estimated magnitude 8.7 earthquake, a tsunami hit the capital city of Lisbon, killing thousands who had fled shaking buildings.

INLAND WAVES
Landslides and volcanic eruptions can launch tsunamis in lakes and rivers

INDIAN OCEAN, 2
A magnitude 9.1 earthquake off the Indonesian island of Sumatra lifted a 1,000-mile stretch of seabed as much as 20 feet; 20 minutes later a tsunami more than 100 feet high struck Sumatra.

COASTAL COLLISION

1 At subduction zones a dense oceanic plate dives under a continental one. Strain builds up where they get stuck.

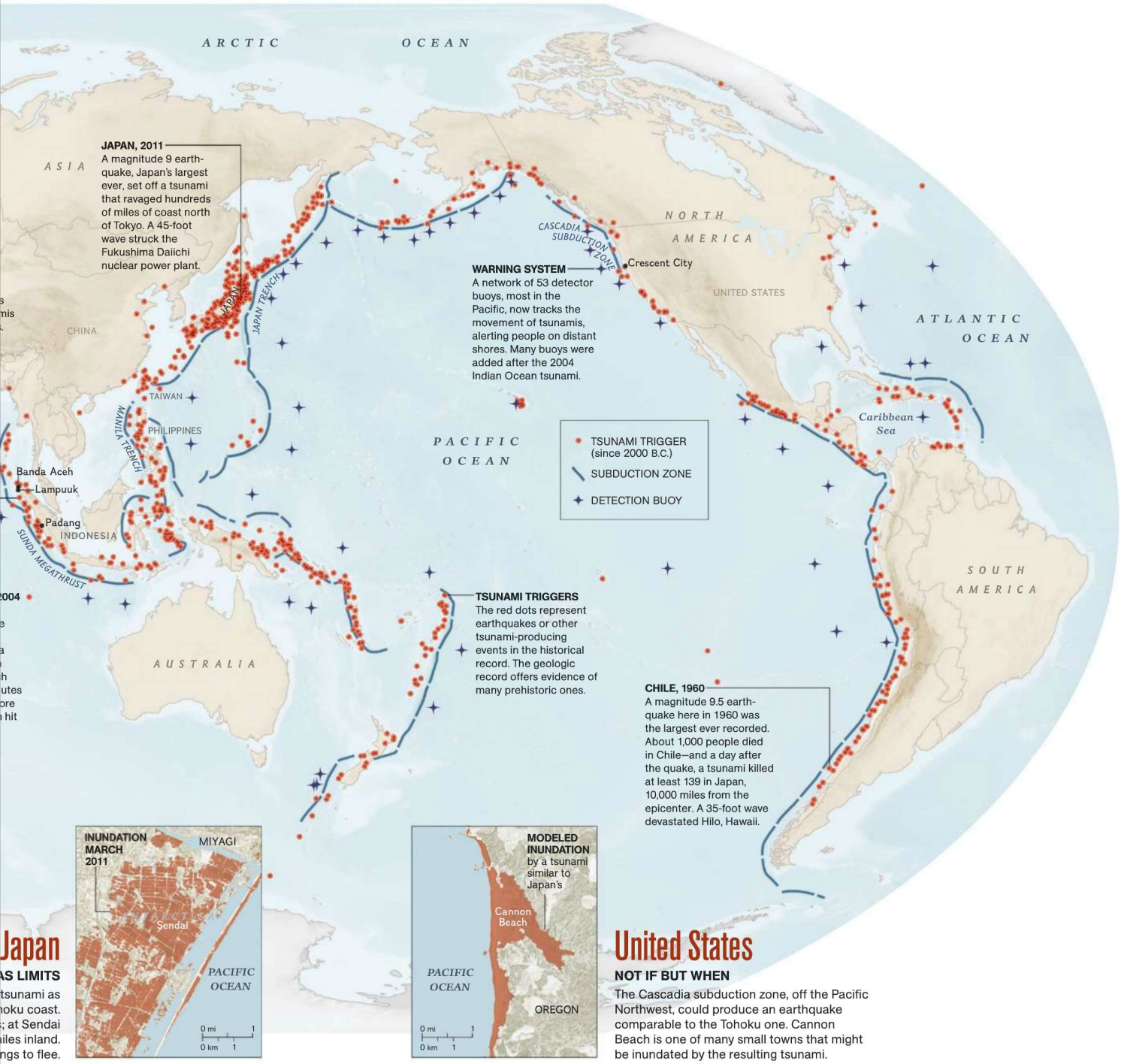
2 When the plates lurch free in a quake, the seafloor may buckle, lifting the sea—triggering a tsunami.

3 Before the first wave arrives, water often recedes from the shore, draining harbors and exposing the seabed.

4 The first wave is not the last. Towering waves may batter a nearby coast for hours, racing miles inland.

PREPAREDNESS HA

Japan had prepared—but not for a large as the one that struck the Toh The waves crashed over tall seawalls they penetrated more than two m Many people ignored warni



Japan

AS LIMITS

tsunami as
hoku coast.
; at Sendai
iles inland.
ngs to flee.

United States

NOT IF BUT WHEN

The Cascadia subduction zone, off the Pacific Northwest, could produce an earthquake comparable to the Tohoku one. Cannon Beach is one of many small towns that might be inundated by the resulting tsunami.

ART: BRYAN CHRISTY. MAPS: WILLIAM E. McNULTY, NGM STAFF; TED SICKLEY. ART SOURCE: OREGON STATE UNIVERSITY. MAP SOURCES: NATIONAL GEOPHYSICAL DATA CENTER/WORLD DATA CENTER (NGDC/WDC) GLOBAL HISTORICAL TSUNAMI DATABASE; IAN MADEN, OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES; GERMAN AEROSPACE CENTER, CENTER FOR SATELLITE BASED CRISIS INFORMATION


観 泉 洞
三 王 岩
浄 土 ケ 浜
シートピアなあど



Black with muck scoured from the harbor, the first tsunami wave pours over a seawall in Miyako, carrying vans and boats. Japan's defenses were no match for waves far higher than scientists had predicted.

JIJI PRESS/AFP/GETTY IMAGES

By Tim Folger

Jin Sato is the mayor of a town that no longer exists.



As waves battered the disaster-readiness center

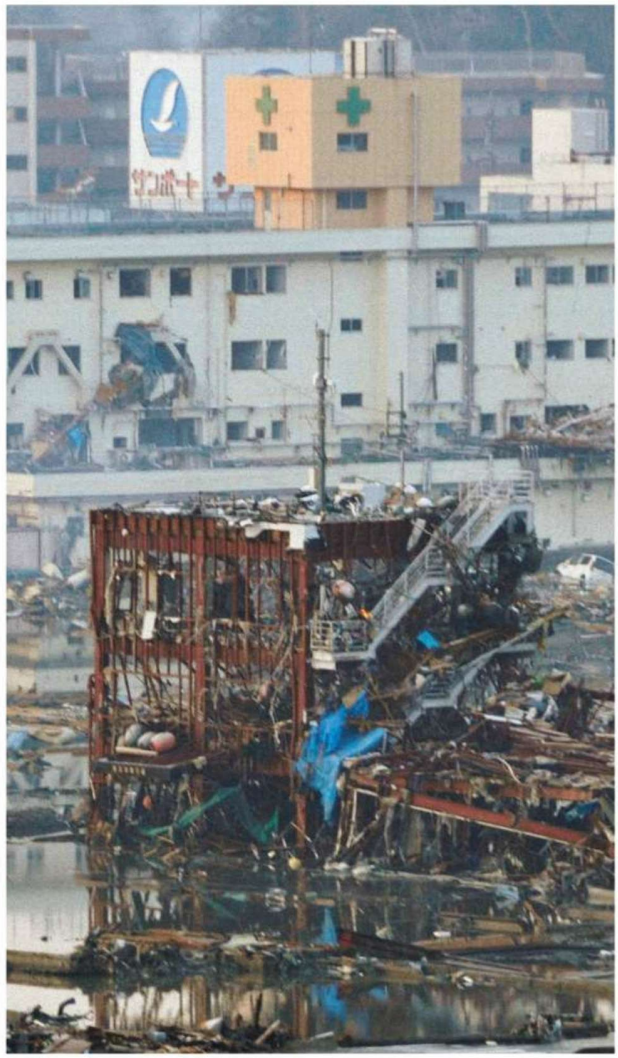
Minamisanriku, a quiet fishing port north of Sendai in northeastern Japan, disappeared last March 11. Sato nearly did too. The disaster started at 2:46 p.m., about 80 miles east in the Pacific, along a fault buried deep under the seafloor. A 280-mile-long block of Earth's crust suddenly lurched to the east, parts of it by nearly 80 feet. Sato had just wrapped up a meeting at the town hall. "We were talking about the town's tsunami defenses," he says. Another earthquake had jolted the region two days earlier—a precursor, scientists now realize, to the March 11 temblor, which has turned out to be the largest in Japan's history.

When the ground finally stopped heaving, after five excruciating minutes, Minamisanriku was still mostly intact. But the sea had just begun to heave. Sato and a few dozen others ran next door to the town's three-story disaster-readiness center. Miki Endo, a 24-year-old woman working on the second floor, started broadcasting a warning over the town's loudspeakers: "Please head to higher ground!" Sato and most of his group headed up to the roof. From there they watched the tsunami pour over the town's 18-foot-high seawall. They listened to it crush or sweep away everything in its path. Wood-frame houses snapped; steel girders groaned. Then dark gray water surged over the top of their building. Endo's broadcasts abruptly stopped.

Some 16,000 people died that day, most of them along hundreds of miles of coast in the Tohoku region, and nearly 4,000 are still missing. The tsunami eradicated several towns and villages in Tohoku and left hundreds of thousands homeless. In Minamisanriku the killed or missing number about 900 of 17,700 inhabitants, including Miki Endo, whose body was not found until April 23. Sato survived by climbing a radio antenna on the roof and clinging to it. "I think I was underwater for three or four minutes," he says. "It's hard to say." Many of the 30 or so other people on the roof tried to hang on to the iron railings at its edge. The waves kept coming all night long, and for the first few hours they repeatedly inundated the three-story building. In the morning only ten people remained on the roof.

Japan leads the world in preparing for earthquakes and tsunamis. It has spent billions retrofitting old buildings and equipping new ones with shock absorbers. High seawalls shield many coastal towns, and well-marked tsunami evacuation routes lead to high ground or to tall, strong





in Minamisanriku, ten people—including Mayor Jin Sato—survived by clinging to handrails and a radio antenna.

buildings. On March 11 government seismologists had barely stopped hugging their computer monitors to keep them from crashing to the floor when their first tsunami warning went out.

Together these measures saved many thousands of lives; Miki Endo alone may have saved thousands. The Tohoku earthquake itself—a magnitude 9—did much less damage than it would have in other countries. But between 16,000 and 20,000 died because of the tsunami—a death toll comparable to that caused by an earthquake and tsunami in the same region in 1896.

Japan's defenses have improved tremendously since then, but its population has tripled. Its coasts are far more crowded. The same is true all over the world, in countries that are much less prepared. In the Indian Ocean, where the deadliest tsunami in history killed nearly 230,000 people in 2004, most of them in Indonesia, a similar disaster has been forecast for sometime within the next 30 years. In the United States, where a tsunami devastated the Pacific Northwest 300 years ago, when it was sparsely inhabited, geologists say another is inevitable. It's likely there will be many Minamisanrikus in the decades ahead.

Sato had survived a big tsunami before. In 1960, when he was eight, a 14-foot wave killed 41 people in Minamisanriku. The seawall was built after that, to a height of 5.5 meters, a little over 18 feet. "We thought we would be safe," Sato says. "Seismologists had told us to prepare for a tsunami that might be five and a half to six meters high. But this one was three times that height." Afterward, in the landscape of debris that had been his town, almost the only thing that remained intact was the seawall.

TSUNAMIS STRIKE somewhere in the world almost every year, and giant ones have arguably

SHINICHI SATO, KYODO/AP IMAGES (ALL)


NO DIVE



Something always draws people back to the sea—and to facsimiles thereof. At the Summerland wave pool in Tokyo last August hundreds of fun seekers found relief from a hot afternoon and from months of tragic news.

MICHAEL YAMASHITA

changed history. Some archaeologists have argued, for instance, that a Mediterranean tsunami struck the north shore of Crete a bit over 3,500 years ago; the disaster, they say, sent Minoan civilization, one of the most sophisticated of the age, into a tailspin, leading it to succumb to Mycenaean Greeks. In 1755, when an earthquake and tsunami killed tens of thousands in Lisbon, the tragedy had a lasting impact on Western thought: It helped demolish the complacent optimism of the day. In Voltaire's novel *Candide* the blinkered philosopher Pangloss arrives in Lisbon during the catastrophe, persists in arguing that "all is for the best in the best of all possible worlds," and gets hanged for his trouble. Voltaire's withering satire made it a little harder to be Panglossian—to believe that a benevolent God designed an optimal Earth.

Tsunamis remain dangerous after they've crossed a whole ocean, barreling at the speed of a jetliner. The one that savaged Japan swept a man in California out to sea.

In the fifth century B.C. the Greek historian Thucydides was the first person to document the connection between earthquakes and tsunamis. He noticed that the first sign of a tsunami is often the abrupt draining of a harbor, as the sea pulls away from the coast. "Without an earthquake I do not see how such things could happen," he wrote. Actually they can. The Minoan tsunami was triggered by the cataclysmic eruption of Thira, a volcanic island 70 miles north of Crete in the Aegean. And landslides can cause local tsunamis, such as the one that surged 1,700 feet up a hillside in Lituya Bay, Alaska, in 1958 (see page 70). All it takes is a large mass of rock moving abruptly in a large mass of water—not necessarily the ocean.

Tim Folger's article on rare earths appeared last June. His family hails from Nantucket, but he lives now in Gallup, New Mexico, far from the sea.

The vast majority of tsunamis, however, including the Tohoku one, are caused by seafloor earthquakes along faults called subduction zones. Most are in the Pacific and Indian Oceans. Along those boundaries two of Earth's tectonic plates collide, and the one carrying dense oceanic crust dives under the more buoyant continental one, forming a deep-ocean trench. Normally this happens smoothly, at a rate of a few inches a year. But at some times and places the plates become stuck—the peak of a subducting seamount might snag on the bottom of a continent, for example. After centuries the accumulated strain overwhelms the friction, and the plates shudder past each other. Off Japan last March the quake began miles below the seafloor and then spread up the sloping contact between the plates to the Japan Trench at the seafloor. It released the energy equivalent of 8,000 Hiroshima bombs. A sizable fraction of that went into motion of the seafloor, which raised and lowered the water above it—thus creating a tsunami.

Ordinary ocean waves are mere wind-driven wrinkles in the sea surface, but a tsunami moves the entire water column, from the seafloor up. The initial disturbance spreads out in opposite directions from the fault, in long wave fronts that may be a few hundred miles apart. In deep water offshore they're barely noticeable. They grow to dangerous heights only in shallow water, as they pile up against a coast—and they can remain dangerous even after they've crossed a whole ocean, barreling at the speed of a jetliner. The tsunami that savaged Japan last March swept a man in California out to sea; it broke Manhattan-size blocks of ice off the frozen margins of Antarctica. The tsunami that took 41 lives in Minamisanriku in 1960 was triggered by a magnitude 9.5 earthquake off Chile, the largest quake on record.

The Indonesian tsunami of December 26, 2004, killed people all around the Indian Ocean. It began off the northwest coast of Sumatra with a sudden, thousand-mile-long rupture—and

magnitude 9.1 quake—on the Sunda megathrust, a fault along which part of the Indian Ocean floor subducts under Indonesia. Indonesia suffered more than any other country, with nearly 170,000 dead—more than half of them in Banda Aceh, the capital of the north Sumatran province of Aceh. But some 60,000 more died in Sri Lanka, in India, and in other countries around the basin, as far away as Africa.

IN THE WAKE OF that unprecedented disaster several countries worked together to expand the use of a tsunami-detecting system that had been developed in the United States by the National Oceanic and Atmospheric Administration (NOAA). The system consists of an instrument anchored to the seafloor—called a tsunameter—that measures pressure changes caused by a passing tsunami. The tsunameter sends a signal to a surface buoy, which relays the data to a satellite, which broadcasts the information to warning centers around the world.

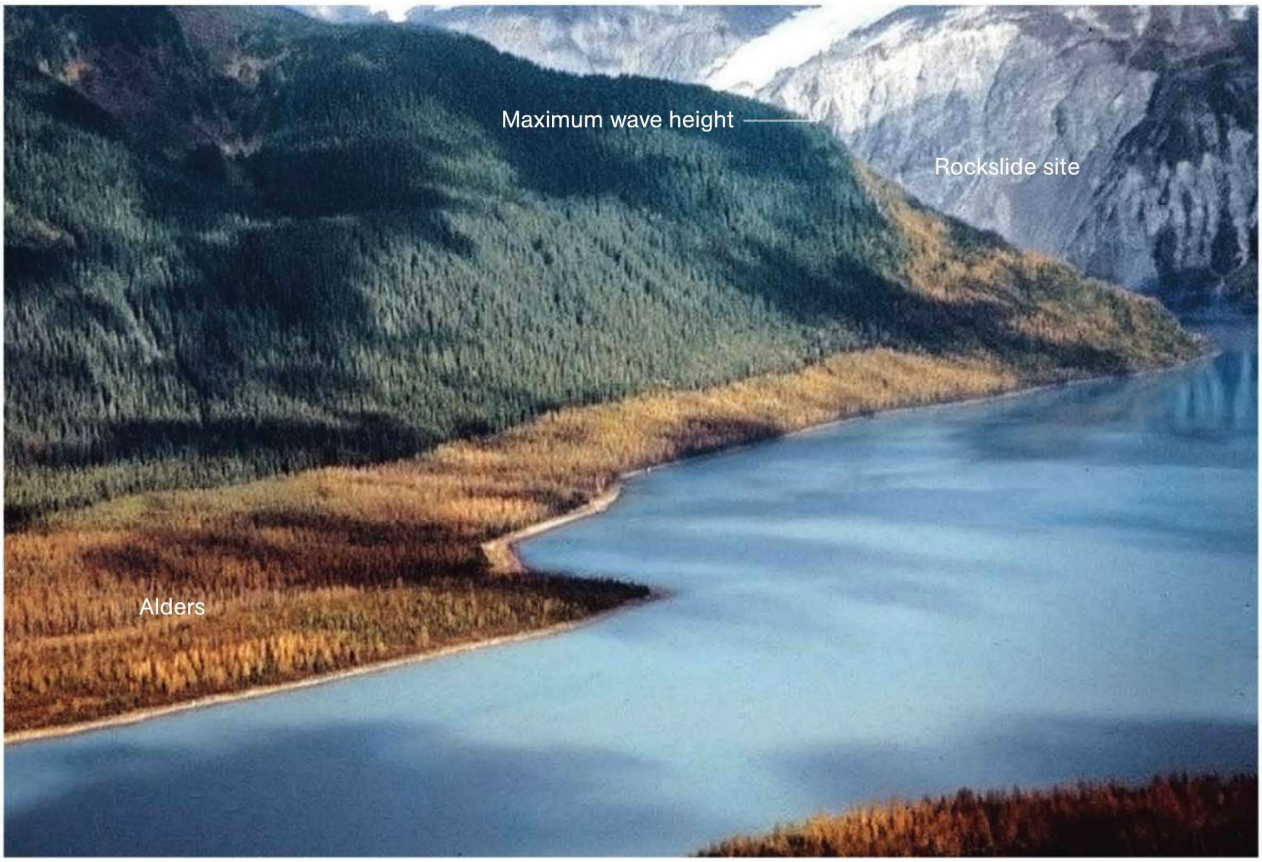
By 2004 only six such detectors had been deployed, all in the Pacific. There were none in the Indian Ocean, and in any event many countries in the region had no national warning centers that could have alerted local communities. That policy blunder had tragic consequences. In Sumatra people had only a few minutes to run, but the tsunami took two hours to reach India, and some 16,000 people died there. "It was totally unnecessary," says Paramesh Banerjee, a geophysicist at Nanyang Technological University in Singapore. "Technically it would have been relatively easy to install a tsunami warning system for the Indian Ocean."

There are now 53 detector buoys operating in the world's oceans, including 6 of a planned 27 in the Indian Ocean. So a repetition of the 2004 horror, in which the tsunami traveled for hours and still caught people by surprise, is less likely. But buoys would not have helped in Sumatra. People living on coasts near a rupturing fault can't wait for confirmation that a tsunami is on its way, which it often isn't; they must flee as soon as the quake hits. The Japanese warning system relies not only on tsunameters but also on seismometers—a thousand of them blanket the country, the densest network anywhere—combined with a computer model that forecasts the scale of a tsunami from the magnitude and location of the quake.

In March the system, which is run by the Japan Meteorological Agency (JMA), did not work perfectly. JMA's crucial first estimate, while the ground was still shaking, put the quake magnitude at 7.9—whereas later analysis revealed a quake that, at magnitude 9, was 12 times larger. The tsunami forecast warned of waves of ten feet or more—whereas they reached 50 feet in Minamisanriku and in some places perhaps even higher. But the human response to the warning was imperfect as well. "I think this time many people who lived above the high-water mark of the 1960 tsunami didn't bother to run," Jin Sato says. "Many of them died." The town's seawall, he thinks, also gave people a false sense of security.

The size of the earthquake and tsunami shocked seismologists. The Indonesian quake had ruptured a thousand miles of fault, the Tohoku quake only 280 miles—and yet the latter produced a magnitude 9 quake. Most geologists didn't think the Japan Trench could do that, even with a longer rupture. The oceanic crust there is old, cold, and dense, and scientists reasoned it would sink beneath Japan too readily and with too little friction to generate such a big quake.

Yet there was evidence that such a quake was possible. More than a decade ago scientists from Tohoku University, in Sendai, dug into the black mud around their coastal city and discovered three separate layers of sand that extended almost three miles inland. Abundant marine plankton in the sand layers showed they had been deposited by giant tsunamis at intervals of 800 to 1,100 years over the previous 3,000 years. The researchers' paper was published in 2001 in the Japanese *Journal of Natural Disaster Science.* It concluded with a warning: Because the last tsunami had struck Sendai more than 1,100 years earlier, the risk of another soon was very high. But to Japanese policymakers the uncertainty in that forecast seemed high too. When the tsunami came last



SPLASH OF THE CENTURY

In the fall, brown alders along the shore of Lituya Bay, Alaska, still trace the path taken in 1958 by the tallest tsunami ever recorded. When an earthquake dropped some 40 million cubic yards of rock from the bare slope in the background into the head of the fjord, the splash surged 1,700 feet up the opposite hillside—higher than the Empire State Building. As the wave barreled toward the mouth of the bay, where it was still more than 25 feet high, it flattened millions of conifers, which have since been replaced by alders. It killed two people on an anchored boat.

March, it deposited another layer of sand at least two and a half miles inland.

"I THINK ALL SUBDUCTION zones are guilty until proven otherwise," says Kerry Sieh. Sieh, director of the Earth Observatory at Singapore's Nanyang Technological University, is one of the world's leading paleoseismologists—he plumbs the geologic record for evidence of ancient earthquakes and tsunamis. He's a delicately built man of 61, with graying, neatly trimmed hair. The historical record—and especially the modern instrumental record—is too short, he says. It absolves long-dormant faults around the world that very likely could generate killer tsunamis. "We must assume every long subduction zone is capable of producing great earthquakes and tsunamis," Sieh says. "We can't assume that any megathrust is gradually and harmlessly releasing strain."

Sieh pulls up a map on his computer. "This is the Manila Trench," he says, pointing to a line that begins off the west coast of the Philippines and continues north to Taiwan. "It's 800 miles long and hasn't done anything big in 500 years. If it broke in a magnitude 9, it would have very serious consequences along the Chinese coast—the

CHARLES AND EMMA JEAN MADER, MADER CONSULTING

tsunami would focus right on Hong Kong and Macau. We don't know if it will break, but I think we have to assume that it can. And there are many others."

Among them is the Cascadia subduction zone, a 600-mile-long offshore fault that runs from northern California to southern British Columbia. Geologists have found sand deposits up and down the coast that were laid down by a tsunami 312 years ago, in 1700. Recent evidence from seafloor sediment cores suggests to some that about 40 earthquakes have occurred along the Cascadia fault zone over the past 10,000 years, an average of one every 250 years; other researchers estimate the recurrence interval at 500 years. When the fault does rupture, most agree, the earthquake could be as large as the one that hit Japan last March, and the tsunami could reach the coast in 20 minutes.

A lot will depend on the season, says Nathan Wood, a geographer with the U.S. Geological Survey in Vancouver, Washington. "The Pacific Northwest coast is sparsely populated for the most part, and many people are less than a mile from high ground," Wood says. "But in the summer there can be 100,000 people on the coast. We could have tens of thousands of deaths."

In Washington there are tsunami evacuation signs, tall towers on the beaches to broadcast warnings, and tsunami information booklets in hotel rooms, next to the Gideon Bibles. But evacuation centers are sparse, and not everyone has access to high ground. Ocean Shores, a resort town that NOAA lists as "tsunami-ready," lies on a narrow peninsula with no high ground and just one two-lane road to safety; 5,500 people live there year-round, many more in the summer. One evening last summer I drove around the town with Jody Bourgeois, a geologist at the University of Washington. "These people are toast, soggy toast," she said glumly.

Seattle, tucked away in Puget Sound behind the Olympic Peninsula, would probably not be hard hit by the tsunami, though it would certainly feel the shaking from a Cascadia quake. But geologists have discovered smaller, shallower cracks in the crust that extend under Puget Sound. "The picture has just started to come together in the last two decades," says Bourgeois. "It's a major, major hazard." The earthquake from a shallow fault could be extremely destructive, and a moderate tsunami launched right off Seattle might be even more damaging than a giant one off the coast. It's not clear how often such events happen in Puget Sound. The last one was about a thousand years ago.

THE FAULT THAT most worries Sieh, though, is the Sunda megathrust. He had been studying it for a decade before it caused the 2004 tsunami; a few years ago he gave up a tenured professorship at Caltech and moved to Singapore in part to be closer to the fault. It stretches 3,700 miles from Myanmar to Australia. The 2004 quake happened near the northern end. "That particular stretch, from northern Sumatra up to the Andaman Islands, was on nobody's radar screen," says Sieh.

He had been working off Sumatra but several hundred miles to the south, measuring the ages of dead coral reefs. When the seafloor rises during an earthquake, it can thrust a reef above water, killing the corals; radiometric dating reveals when that happened. By 2003 Sieh and his colleagues had reconstructed a disturbing seismic history for west central Sumatra.

"We found what we call supercycles—clusters of big earthquakes occurring at regular intervals," he says. For at least the past 700 years pairs of large earthquakes had occurred about every 200 years on that segment of the Sunda megathrust, with the earthquakes in each pair separated by roughly 30 years. There had been a pair around 1350 and 1380, another in the early to mid 1600s, and a third in 1797 and 1833—two centuries ago. It looked like another pair of quakes was due.

The discovery worried Sieh so much that in July 2004 he and his colleagues began distributing posters and brochures on the Mentawai Islands, where they were doing their research, warning people about tsunamis. Five months later northern Sumatra was devastated, and Sieh's group received a lot of publicity. "We got



INDONESIA

A U.S. Marine helicopter loaded with food flies over Lampuuk in northern Sumatra on January 4, 2005, nine days after a tsunami killed most of the village's 7,000 residents—and some 230,000 people on coastlines around the Indian Ocean. Many locals believe divine intervention saved the Rahmatullah mosque.

JOHN STANMEYER

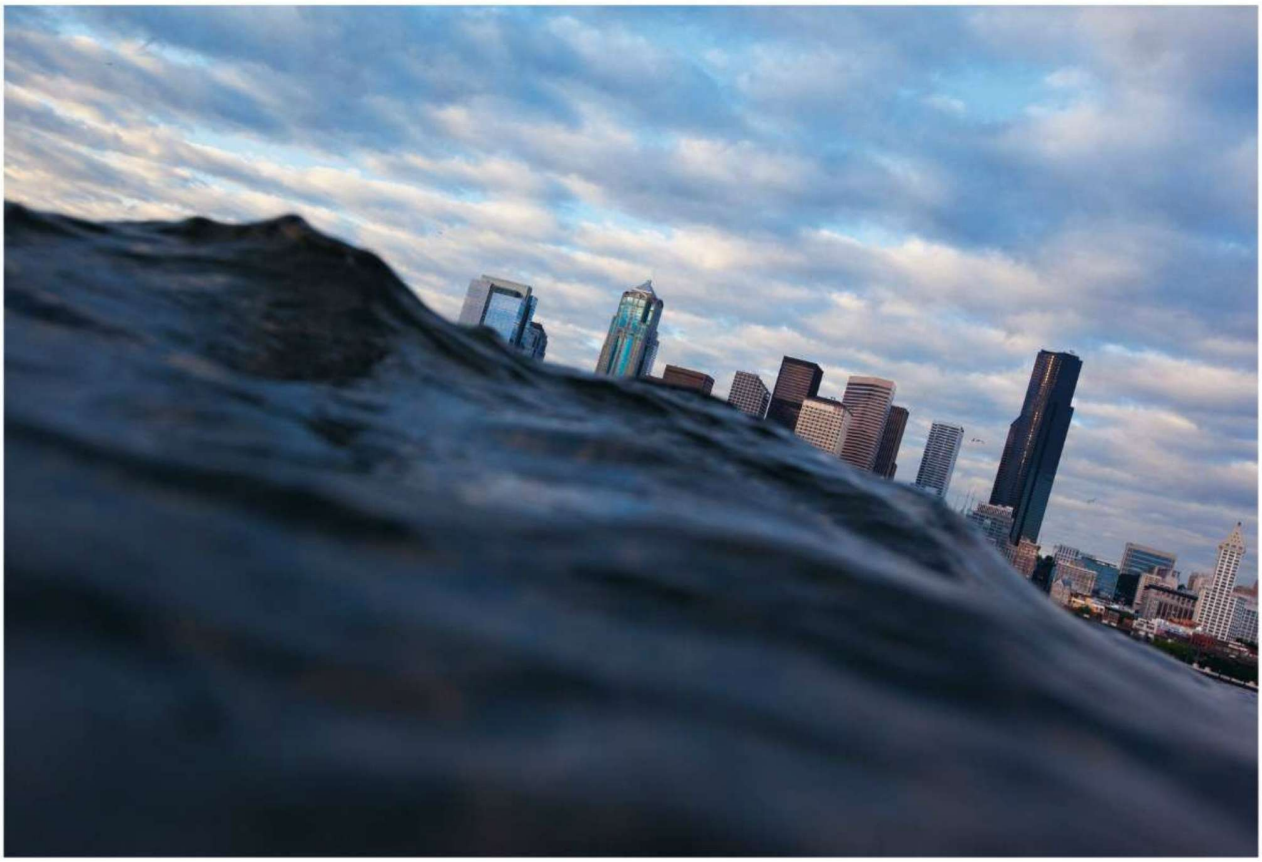

MARINES





In March 2005 a second earthquake off Sumatra unleashed only moderate waves—but lowered the land in some coastal areas by three feet, triggering flooding. On Pulau Balai, Rahmaniar, 23, still walks on coral chunks she used to raise her home's floor above the tides.

JOHN STANMEYER



A fault that runs under Puget Sound could cause a damaging earthquake in Seattle—seen here from a boat floating above the fault—and a tsunami that would strike the waterfront in less than ten minutes.

credit we didn't deserve," he says. "Our forecast was for a different part of the fault." But that forecast still stands—in fact, says Sieh, the first of the anticipated pair of quakes already happened, in September 2007. A magnitude 8.4, it did comparatively minor damage. At Padang, capital of the province of West Sumatra, the tsunami was only around three feet high. Padang is a low-lying city of more than 800,000. Sieh fears it may not fare as well the next time.

"There's never been a more precise forecast of a giant earthquake, period," he says. "Our forecast is for an 8.8 magnitude earthquake in the next 30 years. Nobody can say whether it will be 30 seconds from now or 30 months. But we can say it's very likely to happen within 30 years.

"What are you going to do?" he goes on. "Move the whole city for something that happens once every 200 years? That for me is the quintessential human predicament in regard to these very unlikely but very consequential events. The fundamental problem is not that scientists don't know enough, and it's not that engineers don't engineer enough. The fundamental problem is that there are seven billion of us, and too many of us are living in places that are dangerous. We've built ourselves into situations where we simply can't get away. And I think this will be a century of paying the consequences."

WHEN THE TSUNAMI hits Padang, most people will have no high ground to run to and no more than 20 minutes to run. Much of the city stands less than 15 feet above sea level. The waves could inundate nearly everything within roughly a mile of the waterfront. The open-air restaurants that line the harbor will be swept away first; dark water will surge down streets

JOHN STANMEYER

clogged with motorbikes; thousands of flimsy one- and two-story homes and shops will vanish. The death toll is likely to be much higher than in Japan last March—probably closer to the 90,000 lost in Banda Aceh.

Life in Banda Aceh these days blends the horrific and the miraculous. The cataclysm that left the city strewn with contorted corpses, stripped naked by the waves, also brought peace, ending decades of violent conflict between Acehnese secessionists and the Indonesian government. "During the war you would also see bodies in the streets," says Syarifah Marlina Al Mazhir, program coordinator for the American Red Cross in Indonesia and a Banda Aceh resident. "The tsunami changed everything. And now we can go out at night!" A massive infusion of aid has helped rebuild the city, and young people pack its innumerable cafés late into the night. But everyone knows someone who died on December 26, 2004. "Sometimes when I close my eyes, I can still hear people screaming," one woman told me. In a small park children too young to remember play on a slide in the shadow of a 200-foot-long, 2,600-ton ship, preserved where the tsunami dropped it, on top of some houses, more than a mile inland.

On a sultry July morning in Padang, an elementary school about a half mile from the beach is drilling for the inevitable. At about 10 a.m. an alarm bell rings, and children erupt from their classrooms into the small, sandy courtyard—boys in white shirts and red pants, girls in white blouses and head scarves and ankle-length red skirts. Squatting in circles, they hold their small backpacks over their heads to protect them from debris that might fall during an earthquake. They all chant in unison. "They're repeating the 99 names of Allah," says Patra Rina Dewi. "'The Merciful, the Compassionate, the Guardian.' It's to keep them calm during a real emergency."

Patra, 39, is the energetic head of a small nonprofit tsunami-awareness organization called Kogami, which she and a few friends founded after seeing reports from Banda Aceh. Under pressure from Kogami, Padang has already marked 32 evacuation routes, and nine of a planned hundred multistory shelters are under construction to allow some people to escape the waves. Meanwhile Patra and her staff of 16 have started tsunami drills in schools like this one. Because there is no high ground nearby, the 567 students here have been drilled to run about two miles inland. But the 80 or so first graders can't run fast enough. "The first graders need 40 minutes to reach the safe area," says Elivia Murni, one of the teachers. "They will disappear if the tsunami comes. We won't be able to save them."

There are about a thousand schools along the coast of West Sumatra, and Kogami has started training programs in 232. It won't even try in some of the fishing villages that dot the coast northwest of Padang. "Sometimes I can't sleep at night," Patra says as we leave one of those villages. Lush hills rise to the east, but broad, muddy rice fields would make it impossible to reach the hills in time. "There are no escape routes for them here," Patra says. "If we told them about the tsunami danger, we would only leave them feeling hopeless."

WHEN MARCH 12 FINALLY dawned in Minamisanriku, Jin Sato and his diminished band on the roof were cold, sodden, and utterly exhausted. They climbed down fishing nets that had washed up against the red steel skeleton of the gutted building and made their way up a nearby hill, where other survivors were gathering. Sato's office is now in a prefab building on that hill. He's 60 and trimly built, with thick black hair and glasses and a level, serious gaze. His hands are scarred from gripping the radio antenna. Buddhist prayer beads encircle his left wrist.

The town Sato grew up in is gone, but he is still responsible for many of its people, who are living in shelters or temporary housing. The land here dropped more than two feet after the earthquake, so large parts of the former town flood at high tide. Resurrecting Minamisanriku may prove impossible, and that is a source of anxiety for the survivors. "People want to stay here, where their ancestors lived and died," says Sato. "They don't want to move." □

A time to run

Japan knows what to do when the water suddenly goes away. People don't always heed the warnings.

BY MARIE MUTSUKI MOCKETT

I RECENTLY FOUND old journals I kept as a child while traveling through Japan with my mother. The journals are written in Japanese in pencil, and each entry is accompanied by a picture drawn with colored pen. In one a girl (me) swims off a beach. In another a woman (my mother) carries an umbrella, while a child clings to her back. The mother is knee high in dark blue water. An army of heavy, angry raindrops fills the sky. The day before, we had been to the Nebuta Matsuri in Aomori, a festival in which mammoth lanterns in the shapes of gods and heroes wended through hot, dark summer streets. There was flooding the next day, and though my mother laughed as she carried me to safety, we were afraid. What if the rain did not stop? In another picture I stand under gigantic, chandelier-like ornaments in the city of Sendai; the decorations are part of Sendai's famed Tanabata star festival, in which separated lovers, represented by the stars Vega and Altair, are reunited for just one night.

All these towns have a beach. When we visited, my mother would ask me the same thing. "What do you do if the water suddenly goes away?"

"Run," I would answer.

"Why?"

As I got older, this questioning became annoying. I thought my mother was overdramatic. Born in Japan, she had trained as an opera singer in Europe, where she met my father, an American. They both had a tendency to behave as though they were on a stage. Sometimes I got to be onstage with them. Sometimes I was the audience. It made it tricky to know what to take seriously.

"Come on. Why?" she'd repeat.

"Because it means there is a tsunami."

As an adult, I would sometimes look out at the ocean and try to imagine what it would look like all sucked away. How far back would it go? How would it come back in? What exactly was a tsunami? My mother had never seen one. No one I knew in Japan had ever seen one. Everyone was much more afraid of typhoons or earthquakes, even going so far as to refer to Japan as "earthquake country."

My mother's words and training came back to me when I woke up on March 11 to the terrible news. Places in the Tohoku region that I had visited on my childhood trip had felt the effects of the earthquake and tsunami.



The author holds her 1976 childhood journal depicting Onahama Harbor (at left), which was damaged by the 2011 tsunami. The tall building is a lighthouse.

ROBERT CLARK

Thanks to the diligent work of hundreds of amateur Japanese photographers, we all have a pretty good idea of what it looks like when the water rushes back in. It's still difficult for me to imagine what the ocean looks like when it is sucked out.

Traveling in Japan months after the disaster, I have been struck by how survivors speak about their former friend the ocean. Many Tohoku residents make their living from the sea; they were shocked to see familiar waters so transformed.

Newspapers are filled with stories of those who had 15 to 30 minutes to evacuate to high land. It seems like enough time. Then again, what of those who, like me, were schooled to run but became curious about the mythical beast? Repeatedly, survivors told me stories of residents who went back to their homes after the first wave receded. One man went closer to the ocean to "watch" the tsunami after "missing it" the first time. His mother begged him not to. He insisted, and she accompanied him. Both died.

Post-disaster, the world has praised the patient, stoic nature of the Japanese as they have cleaned up and cared for one another. But these qualities existed before the disaster. It is painful for a culture that prides itself on maintaining harmony, and on its Buddhist nature of compassion, to wonder what more could have been done to prevent 16,000 deaths. Ryoko Mita, 60, who lives in Iwaki and is married to my mother's cousin, lamented: "The tsunami revealed our *yudan* [carelessness] and our *ogori* [overconfidence]."

Centuries-old stones inscribed with warnings of past tsunamis dot the coastline of northeast Japan. But just as I was ambivalent about my mother's warnings, it seems too easy to dismiss an urgent message from the past. Unlike earthquakes, which can occur daily in Japan, tsunamis often skip a generation, giving them a hidden and unpredictable power.

"Do you see the sea differently now?" I asked Rumi Sakuyama, a lifelong resident of Japan's northeast coast. "Such a peaceful ocean…to do such a thing," she replied, gazing out at the now quiet water. "A tsunami like this will probably never happen again during my life." And therein lies the danger. □

Marie Mutsuki Mockett, author of the novel Picking Bones From Ash, *blogs at* mariemockett.com.

TOMORR



OWLAND



Astana, the new capital of Kazakhstan, is brash and grandiose—and wildly attractive to young strivers seeking success.

FLORAL FLOURISHES DECORATE NURZHOL BOULEVARD, OR "RADIANT PATH."



Visitors eagerly match palms with the solid gold handprint of President Nursultan Nazarbayev on the Baiterek monument's observation deck. On special occasions the gesture triggers a recording of the national anthem, said to be written by the president.







Flanked by traditional Kazakh dancers, a bride awaits her formal unveiling at an opulent wedding palace, where she has just been married in a ceremony capped by the release of two white doves. The revelry begins when the veil is lifted.

BY JOHN LANCASTER
PHOTOGRAPHS BY GERD LUDWIG

THE NEW CAPITAL OF KAZAKHSTAN does not lack for exotic buildings, some of them best described by irreverent local nicknames: the banana (a bright yellow office tower), seven barrels (a cluster of apartment towers), the cigarette lighter (the Ministry of Transport and Communications). But one such structure, a national monument called the Baiterek, does not lend itself to nicknames, for the simple reason that it looks like nothing else. Not on this planet, anyway.

Baiterek, which means "tall poplar tree" in Kazakh, is a 318-foot tower buttressed by an exoskeleton of white-painted steel. At the top is a gold-tinted glass sphere. According to the epigraph at its base, the monument represents the Kazakh myth of Samruk, a sacred bird that every year lays a golden egg—the sun—in the crown of an enormous tree of life. Its designer? None other than Nursultan Nazarbayev, the steelworker turned strongman who has run the country since independence from the Soviet Union in 1991. He is said to have roughed out the original concept on a paper napkin.

Just as 18th-century tsar Peter the Great claimed a swampy patch of Baltic seacoast and stamped his brand on St. Petersburg—the national seat of power in imperial Russia—so, too, did Nazarbayev pick out a remote spot on which to plant the flag of a new Kazakhstan. Never mind that the previous capital, Almaty, is a temperate, pleasant city that few save the president wanted to leave. In late 1997 the government officially relocated to frigid, windswept Aqmola, 600 miles to the north, on the treeless steppe of Central Asia. The town was subsequently rechristened Astana—the Kazakh word for "capital"—a change that is commemorated every July 6 on Astana Day, which coincides with Nazarbayev's birthday.

Rich in oil and other mineral resources, Kazakhstan has lavished billions on the new capital, inviting some of the world's leading architects to showcase their work on the Left Bank of the Esil River, which separates the administrative "new city" from the older, mostly Soviet built district on the Right Bank. The results are eclectic, visually arresting, and not to everyone's taste. But love it or hate it, Astana is here to stay, its population having swelled from 300,000 to more than 700,000 in a decade. Along the way, it has become a billboard for Kazakh nationalism and aspirations—a statement as much as a city.

Other capitals have had similar origins, including, of course, St. Petersburg, which Fyodor Dostoyevsky once described as "the most theoretical and intentional town on the whole terrestrial globe." The description was not meant to flatter. But eventually the Russian city took on a life of its own, endured, and prospered. Will Astana do the same?

Yernar Zharkeshov, for one, has no doubt. The polished 24-year-old, dressed in crisp khakis and a polo shirt, meets me for lunch in an upscale Central Asian restaurant on Nurzhol—Radiant Path—Boulevard, which is Astana's equivalent of the National Mall in Washington. He is accompanied by a lovely young woman named Michelle, who is visiting from her native Singapore, where Zharkeshov has recently completed a master's degree in public policy. He orders



The Baiterek, towering over Astana's central promenade, flares green against a dappled evening sky. Intended as a symbol of the new capital, the 318-foot monument evokes a giant tree with a golden egg in its branches. In the Kazakh myth of Samruk, a sacred bird lays a golden egg in the branches of a poplar each year.

horsemeat sausage and koumiss—the fermented and mildly alcoholic mare's milk that is the Kazakh national drink—watching in amusement as Michelle gamely tries a few sips before passing it over to him.

Zharkeshov came by his tastes honestly. The son of a former Communist Party official, he is a member of the ethnic Kazakh group that makes up more than 60 percent of the country's 16 million people. Famed for their horsemanship, the Kazakhs lived as nomads in the centuries before their vast, empty homeland, roughly the size of Europe, was absorbed into the Soviet empire. But the Zharkeshov family worked hard to preserve their Central Asian traditions. They had kept livestock in their village southeast of Astana, where Yernar herded sheep on horseback and made koumiss in a birchwood churn smoked with herbs that grew wild on the steppe.

Six years after the collapse of the Soviet Union, Zharkeshov moved with his parents and four siblings to the new capital, where his father worked for an insurance company and later became a bathhouse owner. Zharkeshov had grown up speaking Kazakh, but by the age of 15 he had mastered both Russian—now as then the dominant language in urban areas of Kazakhstan—and English. He eventually won a government scholarship to study in Britain, where he earned his undergraduate degree before heading to Singapore. He had come home to Astana to hunt for a job.

Zharkeshov was thrilled with the new capital and what it seemed to promise, both for him and for a country that in his view is too often lumped with its unstable neighbors—"there's a problem in being a 'stan,'" he says (or worse, there's ridicule, as in the 2006 hit movie *Borat*). But Astana, says Zharkeshov, is the new face of Kazakhstan. "It's remarkable, seriously, just being part of this process."



Just days after we met, he landed a coveted job as a government economist, joining thousands of other young people—the average age in the city is just 32—for whom Astana has become a beacon of opportunity. Like Zharkeshov, most of the newcomers are ethnic Kazakhs—as opposed to the ethnic Russians, Germans, Ukrainians, and others who make up the balance of Kazakhstan's population. Their dominance reflects the government's preference for hiring people who can speak Kazakh, which irks non-Kazakhs, who see it as further evidence of their diminished status in post-Soviet Kazakhstan.

The emphasis on the Kazakh language is part of a larger trend that some call Khazakhification, with Astana its most conspicuous example and Nazarbayev its most ardent promoter. An ethnic Kazakh, the president was born 71 years ago to shepherds in a village in the southeastern part of the country near Kyrgyzstan. He had labored in an ironworks before casting his lot with the Communist Party, in which he held a senior leadership post at the time of the Soviet collapse. Soon after assuming the presidency, he began laying the groundwork to move the capital from Almaty to Aqmola, in north-central Kazakhstan.

Many were baffled by the choice. Founded in 1830 as a tsarist fort, Aqmola developed as a railroad junction and was known during the Soviet era as Tselinograd. In the 1950s and '60s, it was the focal point of Nikita Khrushchev's Virgin Lands initiative, which aimed to turn the region into the granary of the Soviet empire. By the 1990s, however, the town had fallen on hard times and was mostly known for qualities that would not be found in a chamber of commerce brochure: Temperatures that plunge to minus 60°F in winter, clouds of mosquitoes in summer, fierce winds that kick up dust storms from overharvested fields.

A Moscow-trained violinist named Aiman Mussakhajayeva was among the skeptics. She grew up in Almaty and met Nazarbayev after one of her concerts there in the mid-1990s. The president, impressed by her performance, asked if she would like to start a national music academy. She was delighted by the offer and assumed the academy would be located in Almaty.

When Nazarbayev revealed his plan, Mussakhajayeva thought, What is Aqmola? But she swallowed her doubts and followed the president to the new capital, where she now runs the National University of Arts from a sunlit office suite housed in a vivid blue, circular building that foreigners call the dog bowl. As we finished our conversation there, she asked me to wait a moment. "You want to see the Stradivarius I play?"

Nazarbayev has given several reasons for moving the capital from Almaty, among them its vulnerability to earthquakes and its proximity to the Tian Shan mountains, which limit its room to grow. But geopolitics also played an important role. Nazarbayev is widely believed to have been motivated by fear of Russian territorial designs on northern Kazakhstan, which borders Russia and encompasses a large share of Kazakhstan's ethnic Russian population. In any case, few were willing or able to challenge the authoritarian leader, who remains popular for promoting stability and economic growth despite criticism of his government for corruption and human rights abuses.

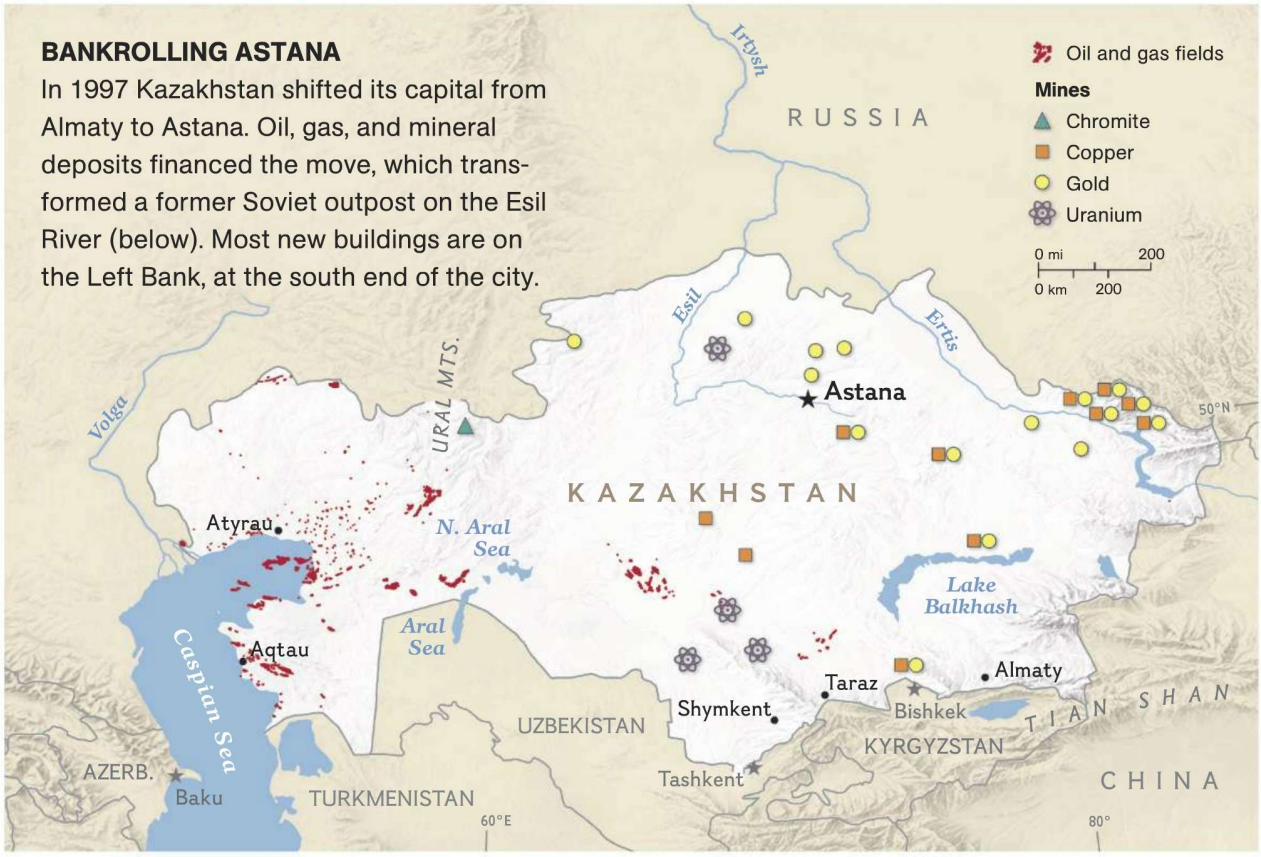
To build his dream city, Nazarbayev solicited help from foreign benefactors eager to do business with Kazakhstan—among them the Persian Gulf emirate of Qatar, which funded construction of a mosque with space for 7,000 worshippers. (Islam is the dominant faith in Kazakhstan, although the state is officially secular.) He also brought in leading global talents such as the late Japanese architect Kisho Kurokawa, who designed Astana's master plan. But he never left any doubt as to who is in charge. Sarsembek Zhunusov, the city's chief architect, recalled his colleagues' trepidation when Nazarbayev declared some years ago that he wanted a huge pyramid built.

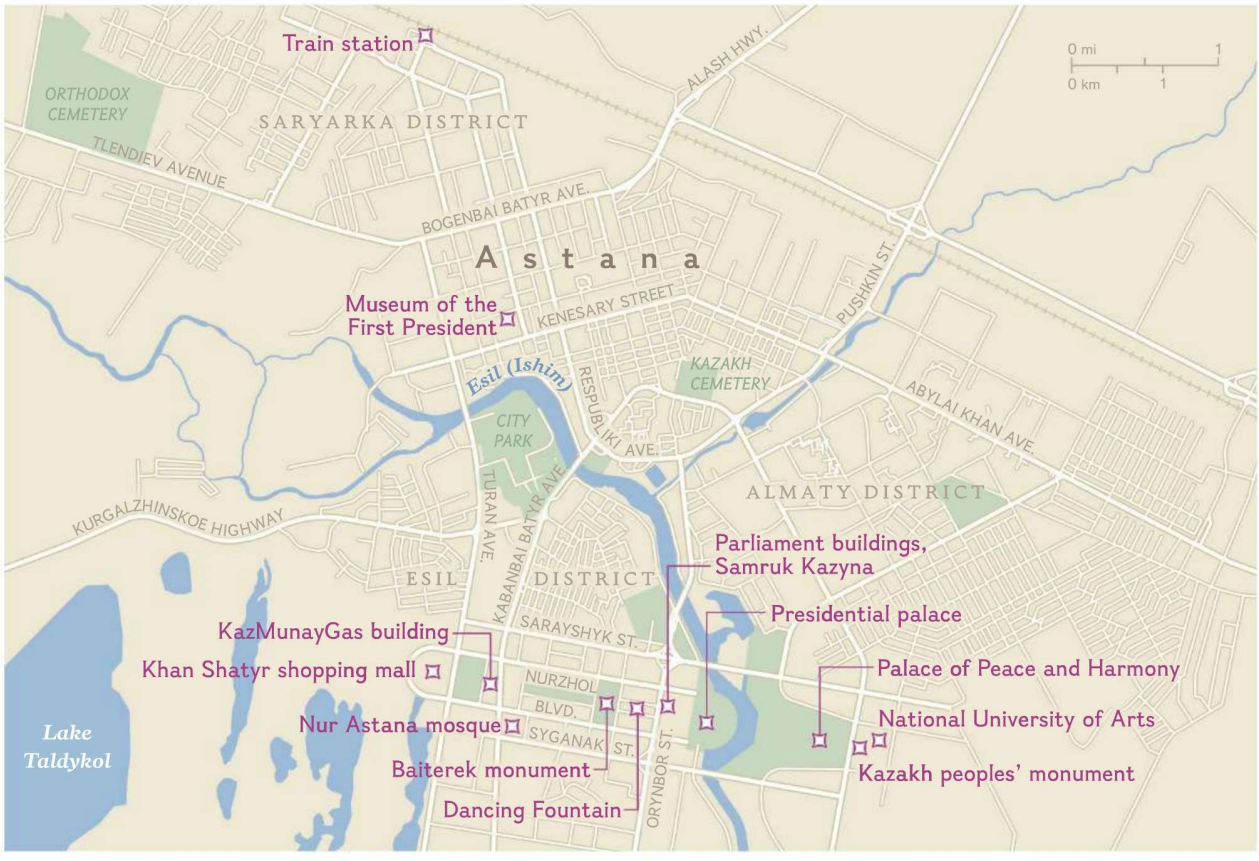
"Our architects kept saying the world already

John Lancaster covered Pakistan's Punjab Province for the July 2010 issue. Gerd Ludwig's photographs of the Crimean Peninsula appeared in April 2011.

BANKROLLING ASTANA

In 1997 Kazakhstan shifted its capital from Almaty to Astana. Oil, gas, and mineral deposits financed the move, which transformed a former Soviet outpost on the Esil River (below). Most new buildings are on the Left Bank, at the south end of the city.





JEROME N. COOKSON, NGM STAFF. SOURCES: USGS; IHS ENERGY



PARLIAMENT BUILDINGS (RED AND BLUE), SAMRUK KAZYNA (GREEN), BAITEREK TOWER



PRESIDENTIAL PALACE

Kazakhstan's new capital is the opposite of understated. After dark, government buildings change hues as the night progresses, creating a theme park atmosphere. The presidential palace suggests a gaudy



KHAN SHATYR



KAZMUNAYGAS BUILDING

version of the White House. Prize-winning British architect Norman Foster is one of many foreigners who helped shape the city. His purple Khan Shatyr shopping mall has an indoor sand beach and wave pool on the top floor.





A flock of giant doves flutters on a stained-glass conference room ceiling at the Palace of Peace and Harmony. The 203-foot-high pyramid designed by Norman Foster provides spaces for worshippers of all religions.

With the core of the capital near completion, Nazarbayev has ordered his architects to explore the possibility of building a huge tent to shelter a climate-controlled "indoor city" of 15,000 people.

has pyramids," Zhunusov said. "Everyone was scared, because you have to be a great architect to build another pyramid." The job of building the Palace of Peace and Harmony ultimately went to Norman Foster, the British architect who is also responsible for the Khan Shatyr, or the "king's tent," a regal, translucent structure vaguely evocative of a yurt.

Signature buildings aside, Nazarbayev remains deeply enmeshed in the minutiae of city planning, down to the choice of flowers—tulips, delphiniums, irises—laid out in vivid patterns derived from Kazakh folklore. "He always has some comments," said Zhunusov. "He worries about something, then he changes his mind in a week because he thinks about it all the time." And he continues to think big. With the core of the capital near completion, Nazarbayev has ordered his architects to explore the possibility of building another huge tent that would shelter a climate-controlled "indoor city" of 15,000 people.

Perhaps the best place to appreciate the scope of Nazarbayev's ambition—and ego—is the observation chamber atop the Baiterek. Amid the 360-degree views and a bar serving cold Turkish beer is a malachite pedestal capped by a 4.4-pound slab of solid gold, in the center of which is an imprint of the president's right hand. Visitors make a wish as they place a palm in the impression, which on special occasions triggers the playing of the national anthem, its lyrics said to have been written by the president.

The city does have its whimsical side. Mesh sculptures covered with vines—swans, horses, giraffes—seem closer in spirit to Disneyland than to Pyongyang. On a balmy evening in June, children blow soap bubbles in the plaza next to the Dancing Fountain, which is illuminated by colored lights as Russian hip-hop pulses from large outdoor speakers. Skateboarders in low-slung jeans perform tricks as police look on indifferently. An outdoor café serves French wine at $17 (U.S.) a glass.

The capital's boomtown ethos may find its fullest expression in its shopping malls, of which the Khan Shatyr—the Foster-designed tent—is the most distinctive. Its top level is taken up by an indoor beach outfitted with a wave pool and sand imported from the Maldives. One night the mall hosted a bikini party, charging $20 for admission. Men and women in skimpy bathing suits downed vodka and Red Bull as a deejay urged, in English, "Everybody get crazy! Ziss iz bikini party!"

More than a dictator's vanity project or a town where rich people party, Astana is a magnet for strivers like Yernar Zharkeshov. And like Darkhan Dossanov, an irrepressible 25-year-old with a lopsided smile who approached me on the street one evening to practice his English. ("I'm really glad to meet you. My English was almost disappeared from my head.")

I ended up buying him dinner, which he devoured so quickly that I wondered how much he had been eating lately. Only six days earlier, he had arrived in the capital with little more than a cell phone and a portable Sony PlayStation, having sold his digital camera to buy a train ticket from his home 500 miles to the east. He had landed a job as a busboy in a fancy Italian restaurant, where he slept on pushed-together chairs before he found lodging in a cramped three-bedroom apartment that he shared with ten others.

When I saw Dossanov again a week or so later, he told me that he had lost his restaurant job because his poor eyesight had prevented him from noticing when tables needed to be cleared. The restaurant was refusing to pay him for eight days of work; he planned to sell his PlayStation to pay for food. Still, he had a line on another restaurant job and remained confident that he had made the right choice in coming to Astana. "I know that in the future I will be very

wealthy," he said. "It's a really lucky place for me."

Indeed, creative and entrepreneurial energy seems to be stirring everywhere among Astana's young people. In a shabby theater on the Right Bank of the Esil River, four young dancers in their late teens and early 20s leaped and twirled through an avant-garde ballet routine under the critical gaze of Adyl Erkinbaev, a 32-year-old dancer and choreographer who wears his hair in a short ponytail.

Erkinbaev is from Kyrgyzstan, where he attended the national ballet school. He moved to Astana in 2002 as part of an initiative by the city government to stock the new capital with artists and performers. Last spring the ballet folded, but Erkinbaev had recruited four of its dancers for an independent production.

None of them seemed to mind that they were rehearsing without wages, at least until Erkinbaev could find a sponsor. "In a good way, he is some kind of mad," said one, Inna Oparina, a 21-year-old ethnic Russian who supports herself as an English teacher. When she first came to him three years ago, she recalled, "I was like a robot. I couldn't express anything." It was Erkinbaev, she said, who taught her that "emotions are more important than technique."

On another night I attended a meeting of young professionals, many educated abroad, who call themselves the Astana Alumni Association. They listened raptly as a guest speaker, 38-year-old Aidyn Rakhimbayev, described his rapid ascent from small-time coal trader to head of one of the country's largest construction firms.

Pressed by a listener for advice on how to turn an idea into a business, Rakhimbayev replied brusquely, "An idea is nothing. Do you have skills? What is your business plan?" He urged them to read books by management gurus such as Tom Peters, while admitting he came late to such pursuits—he was too busy making money. "I made my first million at 29," he says. "In dollars. I made my first ten million at 32. Then I decided it was time to start reading books."

Everyone was looking for an angle. Before my visit ended, I got a call from Yernar Zharkeshov, the newly minted government economist, who asked me to meet him for coffee. We made small talk before he got to the point: His father was trying to set himself up as a consultant to foreign investors and wondered if I could pass along the names of potential clients. Zharkeshov then excused himself to take his nieces and nephews to a showing of *Cars 2,* the Pixar film that had recently opened in Astana to much excitement, in part because it was the first Western movie to be dubbed in Kazakh instead of Russian.

FOR ALL ITS SELF-CONSCIOUS GRANDEUR, there is a tenuous, even temporary, quality to the new capital that came home to me every time it rained, when water poured through the ceiling of the shopping arcade on the first floor of the brand-new apartment tower where I had arranged a short-term rental.

One Saturday afternoon I attended a picnic in a park, thrown by local members of Toastmasters International. A young, American-educated banker approached me, unbidden, to suggest that I should not be too impressed by Astana. "The whole place is like a dream," he said with a wan smile. "It does not sustain itself. It depends on the price of oil, frankly." He paused and shrugged. "We have so many resources we can afford to be stupid at this point."

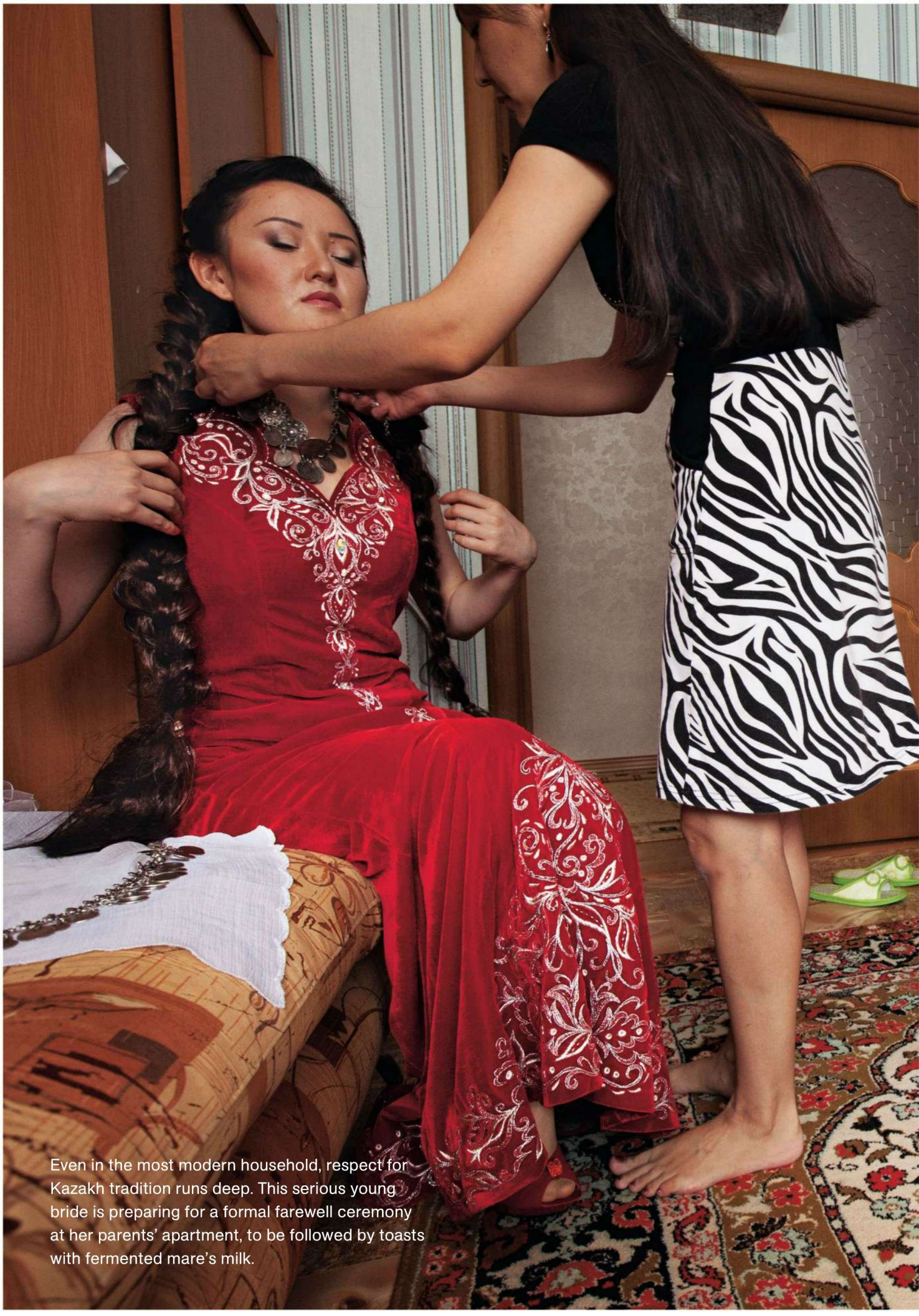
But that was surely a minority view among his fellow picnickers, who spread a blanket in the shade of a poplar tree and heaped their paper plates with beets, oranges, and meat-filled dumplings called *manti.* Someone circulated a bottle of koumiss; a few people began tossing around a Frisbee. "Everyone who loves their job raise your hand," commanded Zhanna Kunasheva, a 33-year-old woman who works for the local office of Shell Oil. Most raised their hands. Kunasheva then handed out copies of lyrics to songs by Frank Sinatra and Russian pop stars, leading the group in an impromptu sing-along.

After a few hours the party broke up, as some of the picnickers announced that they had to go to a Latin dance class. The wind sighed in the poplar trees, and the skyline of the new capital, like the evening, seemed to beckon with a bright and thrilling promise. □





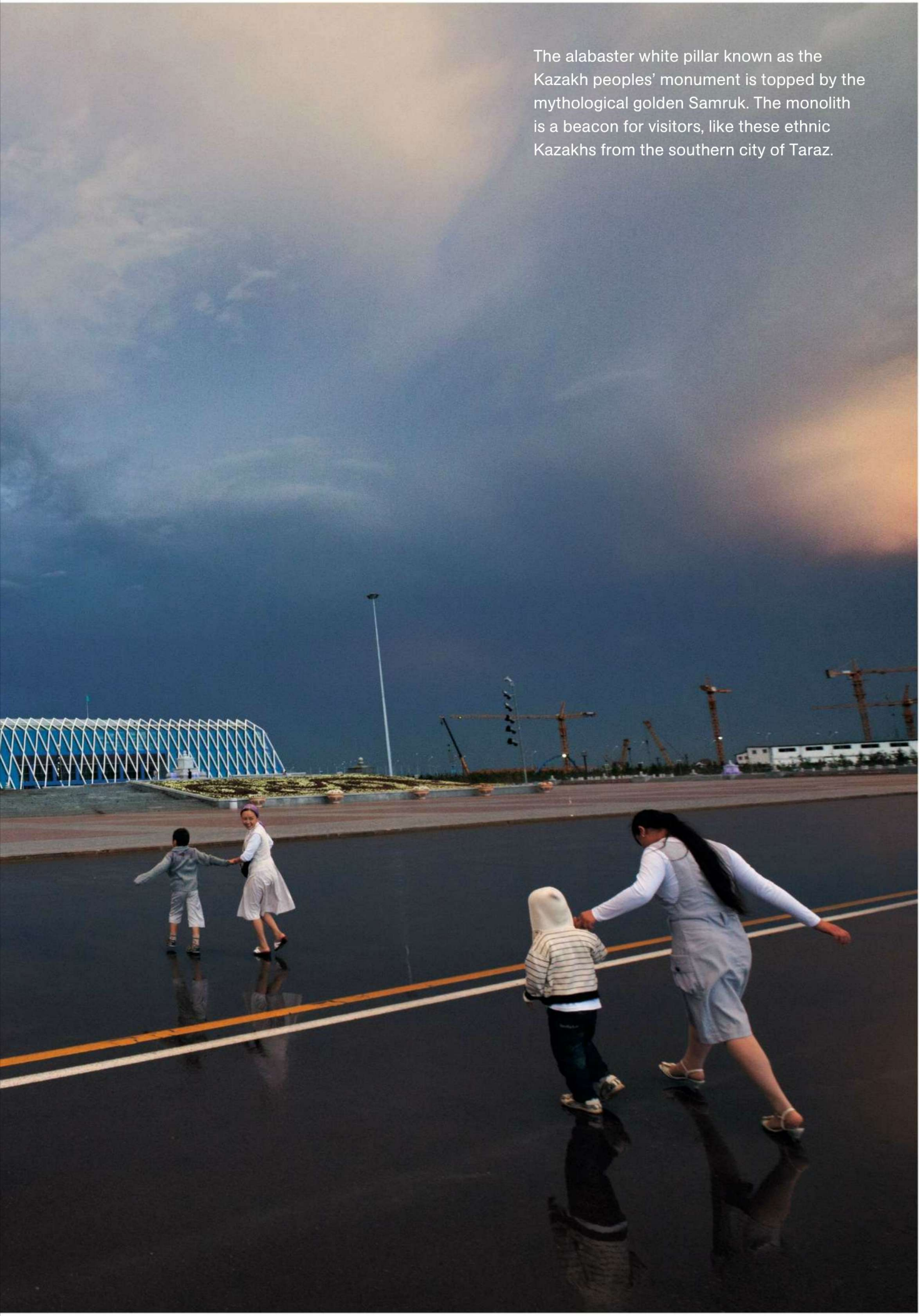
The French Riviera it isn't, but Astana makes the most of its brief summer, when young men gather at the Esil River to flex their muscles before appreciative members of the opposite sex. The cobblestone embankment on the far side is popular with fishermen.



Even in the most modern household, respect for Kazakh tradition runs deep. This serious young bride is preparing for a formal farewell ceremony at her parents' apartment, to be followed by toasts with fermented mare's milk.







The alabaster white pillar known as the Kazakh peoples' monument is topped by the mythological golden Samruk. The monolith is a beacon for visitors, like these ethnic Kazakhs from the southern city of Taraz.

Lady with a Secret

A chalk-and-ink portrait may be a $100 million Leonardo.

By Tom O'Neill

Bianca Sforza attracted few stares when introduced to the art world on January 30, 1998. She was just a pretty face in a frame to the crowd at a Christie's auction in New York City. Nobody knew her name at the time, or the name of the artist who had made the portrait. The catalog listed the work—a colored chalk-and-ink drawing on vellum—as early 19th century and German, with borrowed Renaissance styling. A New York dealer, Kate Ganz, purchased the picture for $21,850.

The price hadn't budged almost ten years later when a Canadian collector, Peter Silverman, saw Bianca's profile in Ganz's gallery and promptly bought it. The drawing might actually date from the Renaissance, he thought. Ganz herself had mentioned Leonardo da Vinci, that magical name, as an influence on the artist. Silverman came to wonder, What if this is the work of the great Leonardo himself?

La Bella Principessa

Evidence of a master

Richly detailed drawing

PEN STROKES ARE BY A LEFT-HANDED ARTIST.

Portrait linked to family book of a Leonardo patron

HOLES ALIGN WITH BOOK'S 15TH-CENTURY BINDING.

KNIFE MARK INDICATES PAGE WAS SLICED OUT OF BOOK.

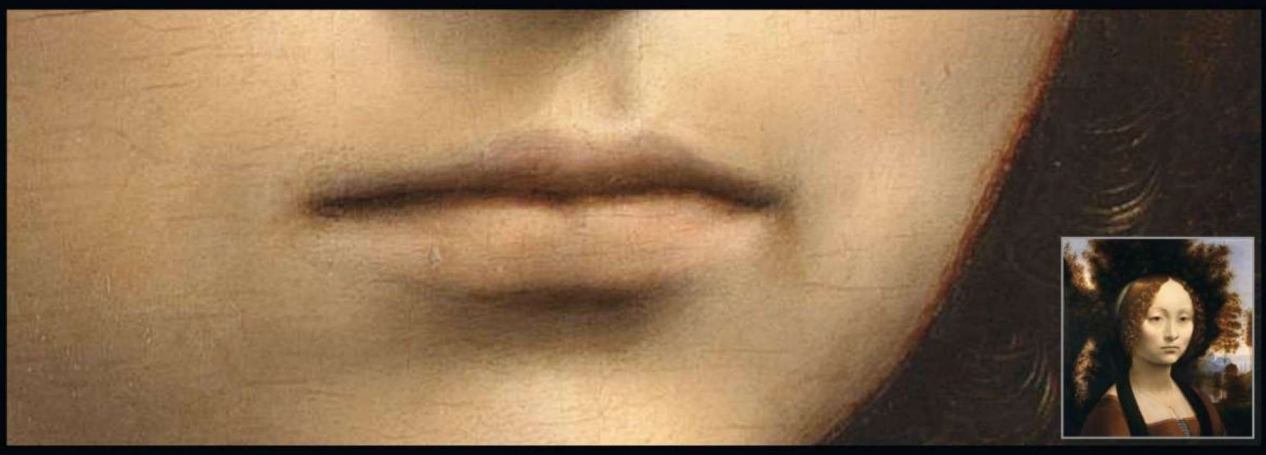
Age verified

VELLUM IS CARBON-DATED TO 1440-1650.

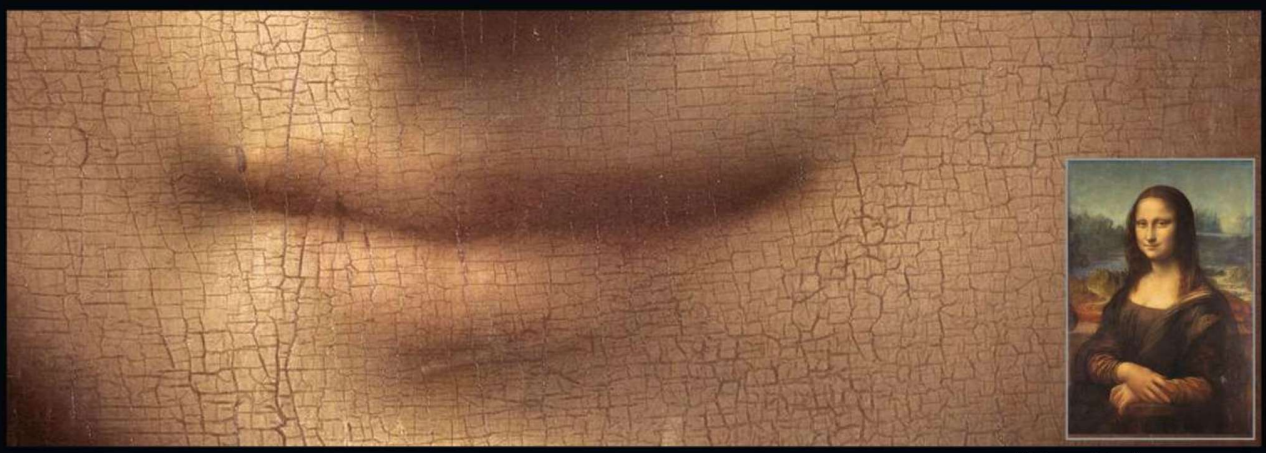
WOMAN'S HAIRSTYLE DATES TO 1490s.



GIANLUCA COLLA



"Ginevra de' Benci," ca 1478



"Mona Lisa," 1503-ca 1510



"Lady With an Ermine," ca 1488-ca 1490

BODY AND SOUL

Leonardo painted women with an unmatched delicacy and depth. In an early portrait (top), completed in Florence, Leonardo displayed his talent for exquisite physical modeling. His mastery of light and shadow brought out the sensual intelligence of the Duke of Milan's mistress (bottom). For his masterpiece "Mona Lisa" (middle), Leonardo, with his innovative use of blurred edges, gave his sitter a smile that breathes a seductive inner life.

FROM TOP: "GINEVRA DE' BENCI," ALISA MELLON BRUCE FUND, IMAGE COURTESY THE BOARD OF TRUSTEES, NATIONAL GALLERY OF ART, WASHINGTON (BOTH); PASCAL COTTE, SIPA PRESS (BOTH); PASCAL COTTE, LUMIERE TECHNOLOGY, WITH PERMISSION OF CZARTORYSKI FOUNDATION (BOTH). OPPOSITE: PASCAL COTTE, LUMIERE TECHNOLOGY

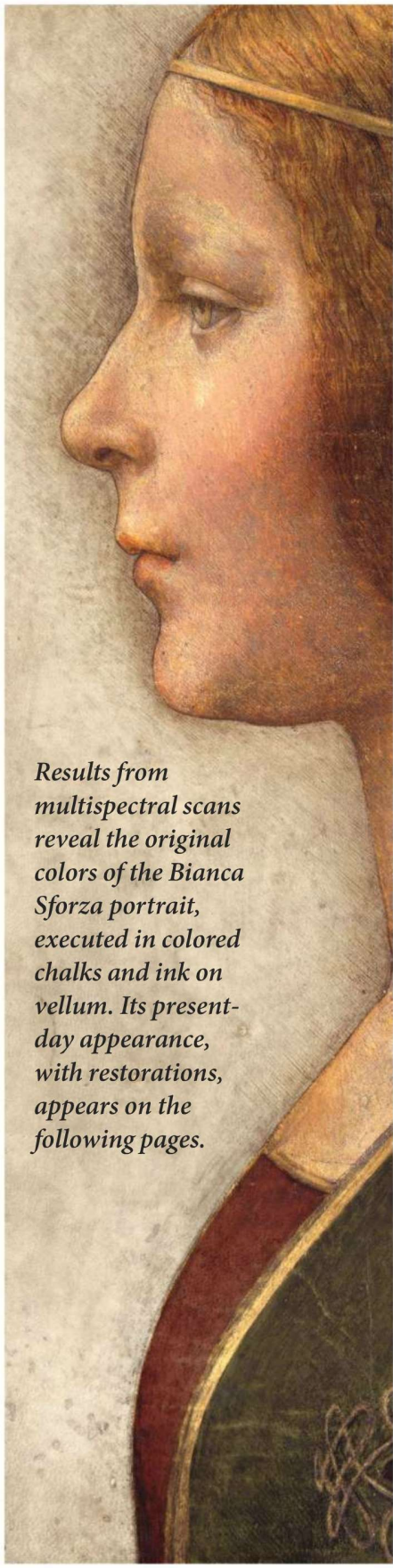
That someone could walk into a gallery and buy a drawing that turns out to be a previously unknown Leonardo masterpiece, worth perhaps $100 million, seems pure urban myth. Discovery of a Leonardo is truly rare. At the time of Silverman's purchase, it had been more than 75 years since the last authentication of one of the master's paintings. There was no record that the creator of the "Mona Lisa" ever made a major work on vellum, no known copies, no preparatory drawings. If this image was an authentic Leonardo, where had it been hiding for 500 years?

Silverman emailed a digital image of Bianca to Martin Kemp. Emeritus professor of art history at Oxford University and a renowned Leonardo scholar, Kemp regularly receives images, sometimes two a week, from people he calls "Leonardo loonies," convinced they have discovered a new work. "My reflex is to say, No!" Kemp told me. But the "uncanny vitality" in the young woman's face made him want a closer look. He flew to Zurich, where Silverman kept the drawing in a vault. At 13 by 9¼ inches, it is roughly the size of a legal pad. "When I saw it," Kemp said, "I experienced a kind of frisson, a feeling that this is not normal."

That initial shiver of excitement compelled Kemp to embark on his own investigation. He was aided by high-resolution multispectral scans by Pascal Cotte of Lumiere Technology in Paris, allowing Kemp to study the drawing's layers, from first strokes to later restorations. The more Kemp looked with his connoisseur's eye, the more he saw what he considered evidence of Leonardo's hand—how the hair bunched beneath the strings holding it in place, the beautiful modulation of colors, the precise lines. Shaded areas showed distinctive left-handed strokes just like Leonardo's. The expression, poised but pensive, the look of someone growing up too fast, conveyed Leonardo's maxim that a portrait should reveal "motion of the mind."

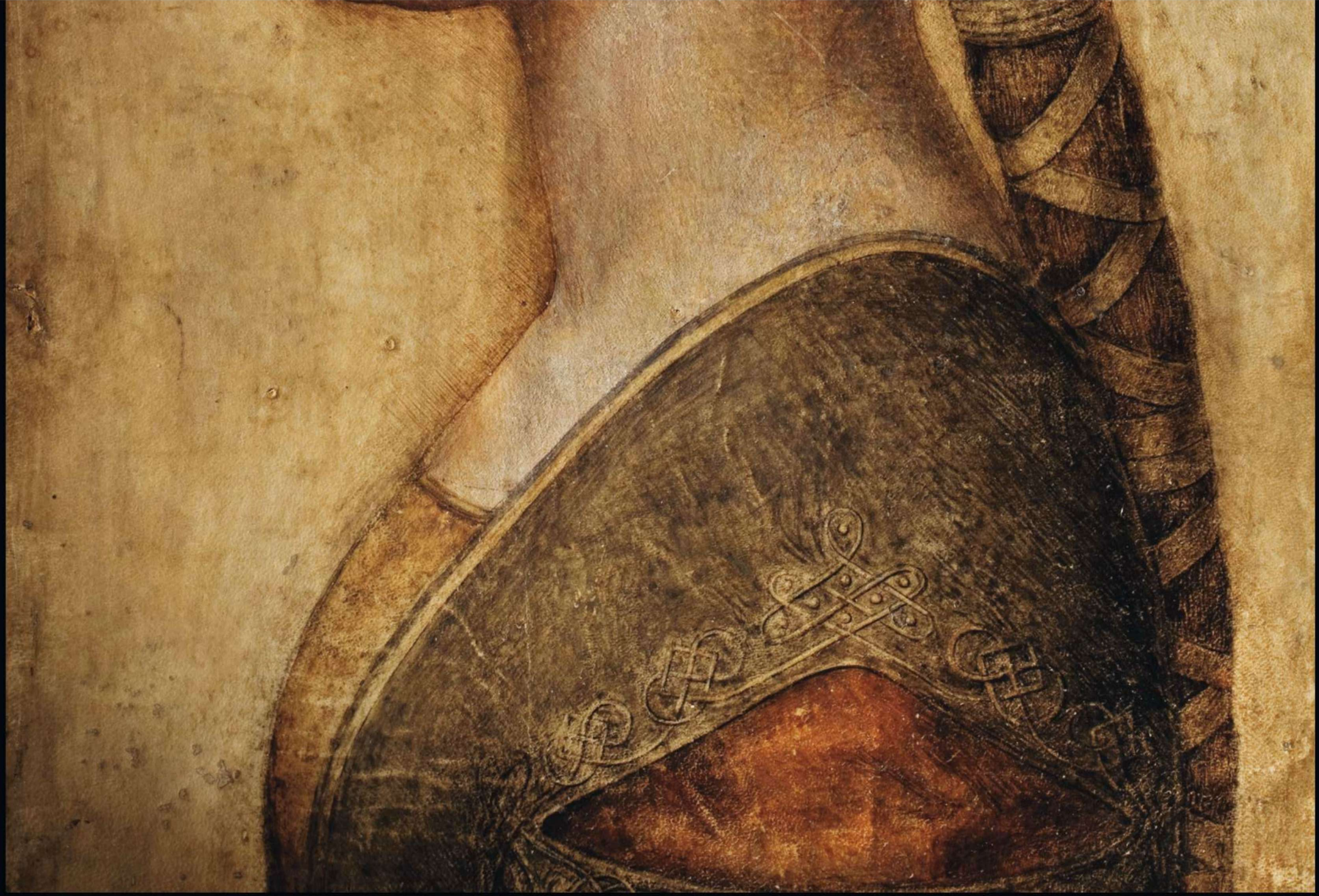
Kemp also needed proof that the portrait had been made during Leonardo's lifetime (1452-1519) and that its historical particulars fit the artist's biography. The vellum, probably calfskin, had been carbon-dated, its origin placed somewhere between 1440 and 1650. Costume research revealed that the sitter belonged specifically to the Milanese court of the 1490s, with its fashion for elaborately bound hair. Leonardo lived in Milan during this time, accepting commissions for court portraits. Stitch marks on the edge of the portrait suggested that it came from a book, possibly one commemorating a royal marriage.

Kemp's detective work led him to a name, Bianca Sforza. An illegitimate daughter of the Duke of Milan, she was married in 1496 to Galeazzo Sanseverino, commander of the Milanese troops and a patron of Leonardo's. Bianca was 13 or 14 at the time of the portrait. Tragically, she died a few months later, likely from an ectopic pregnancy,



Results from multispectral scans reveal the original colors of the Bianca Sforza portrait, executed in colored chalks and ink on vellum. Its present-day appearance, with restorations, appears on the following pages.

Tom O'Neill is a National Geographic *staff writer.*



GIANLUCA COLLA

“La Bella Principessa,” actual size



The moment arrived when they inserted a copy of Bianca's portrait into the open book. It fit perfectly. For Kemp, this was the clincher.

a not uncommon fate for young court brides. Kemp named the drawing "La Bella Principessa," the beautiful princess.

In 2010 Kemp and Cotte published their findings in a book. Several prominent Leonardo scholars agreed, others were skeptical. Carmen Bambach, curator of drawings at New York's Metropolitan Museum of Art, was quoted as saying that the portrait simply "does not look like a Leonardo." Another scholar thought the image too "sweet." The specter of a high-quality forgery was raised. Doubt seemed to collect around the portrait's sudden, almost miraculous appearance. Where had it come from?

Kemp didn't know. Then, almost like divine intervention, a message came from D. R. Edward Wright, emeritus professor of art history at the University of South Florida. Having followed the very public dispute, Wright suggested to Kemp, whom he had never met, that his answer might lie in the National Library of Poland in Warsaw, inside a book called the *Sforziad.* Wright, an expert on Renaissance iconography, described it as a deluxe commemorative volume for the marriage of Bianca Sforza, a fit occasion for a Leonardo portrait.

Funded by a National Geographic Society grant, Kemp and Cotte traveled to Warsaw. Cotte's macrophotography revealed that a folio had been removed from the exact place in the *Sforziad* where a portrait would have been added. The moment arrived when they inserted a copy of Bianca's portrait into the open book. It fit perfectly. For Kemp, this was the clincher: "'La Bella Principessa' was a one-off portrait by Leonardo that had gone into a book and then onto a shelf."

According to Wright, the volume reached Poland in the early 1500s, when a member of the Sforza family married a Polish royal. The leaf was sliced out, possibly at the time of the book's rebinding in the 17th or 18th century. The trail grows faint here. What is known is that at some point it was acquired by an Italian art restorer, whose widow put it up for sale at Christie's.

These are amazing times in the lost-Leonardo arena. In November the National Gallery in London put on exhibit "Salvator Mundi," Leonardo's painting of Jesus Christ holding a globe, a work that had been lost for centuries. In Florence, National Geographic–supported researchers looking for Leonardo's "Battle of Anghiari," last seen in the mid-1500s, are using an endoscope to find out if the painting is hidden behind a wall in the Palazzo Vecchio.

Authenticating a centuries-old artwork, especially a potentially rare, extremely valuable Leonardo, is seldom a clear-cut, objective process. Ego, personal taste, and fear of litigation all get tangled up in the judgment. To reach wider consensus, Kemp sent his latest findings to a number of leading specialists. Almost all refused comment, including for this article. Agreement "will take time," concedes Kemp, "but I have clear confidence in where I am." One thing is sure. Should the day come when Bianca Sforza's face hangs in a museum as a true Leonardo, everyone will stare. ☐

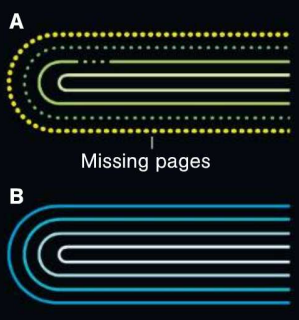
NOVA | NATIONAL GEOGRAPHIC

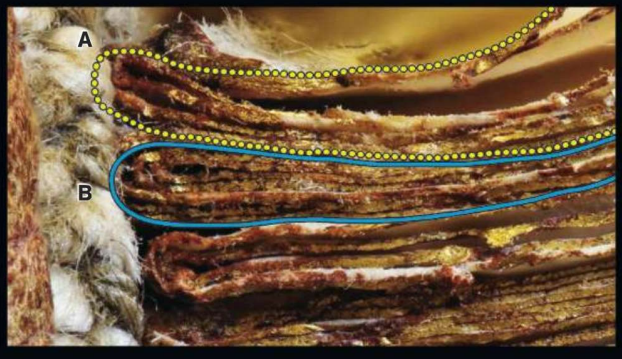
Mystery of a Masterpiece
A new NOVA–National Geographic Special airs Wednesday, January 25, on PBS; check local listings.

Society Grant
Martin Kemp and Pascal Cotte's research in Poland was funded by your National Geographic Society membership.

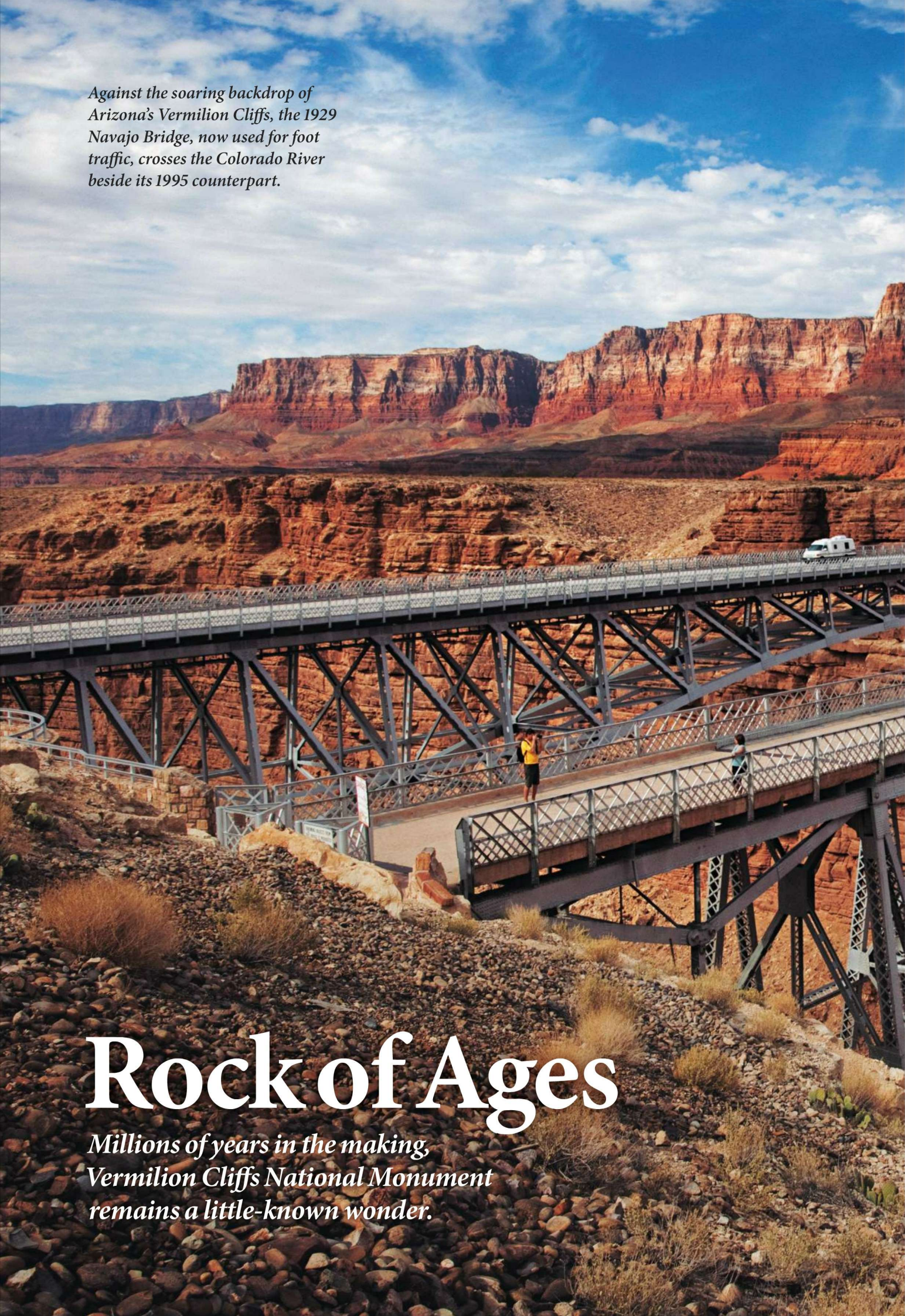
FITTING THE BOOK

A key puzzle piece—the original home of "La Bella Principessa"—appears to have been found in a 500-year-old book at the National Library of Poland in Warsaw. Illustrations in the Sforziad, *commissioned by the Duke of Milan, point to the 1496 wedding of his daughter Bianca Sforza to a Leonardo patron. Macrophotography of the parchment leaves revealed missing pages (below); the bride's portrait would have appeared on the bottom page. As a National Geographic TV crew filmed the moment (above), engineer Pascal Cotte (at left) and Oxford art historian Martin Kemp inserted an exact facsimile of the drawing into the gap. The page fit, its stitching holes lining up. Why and when "La Bella Principessa" was removed remains a mystery.*





GRZEGORZ MAZUROWSKI (TOP); PASCAL COTTE, LUMIERE TECHNOLOGY. NGM ART



Against the soaring backdrop of Arizona's Vermilion Cliffs, the 1929 Navajo Bridge, now used for foot traffic, crosses the Colorado River beside its 1995 counterpart.

Rock of Ages

Millions of years in the making, Vermilion Cliffs National Monument remains a little-known wonder.





Miniature lakes reflect the sky in White Pocket, one of the geological spectacles on the Paria Plateau. Over the eons, groundwater has leached the color out of the Navajo sandstone here, and the weather has broken its surface into irregular polygons.



By Verlyn Klinkenborg

Photographs by Richard Barnes

Carry a lawn chair and a sunshade

—plenty of water too—onto the sage flats just south of Arizona's Highway 89A, near the mouth of Badger Canyon. Point the chair north, toward Utah, and take a seat. Behind you, the Colorado River is trenching a deep meander from the Glen Canyon Dam toward the Grand Canyon. Directly in front of you rises a chaos of rock vaulting nearly 3,000 feet—the Vermilion Cliffs. The cliffs can hardly be said to have a face. They have innumerable faces, fractured and serrated, crosshatched and slumped. You can feel the inertia in their colossal vertical fissures. Along the lower wedding cake tiers, rubble piles resemble the sand in the bottom of an hourglass.

And now the question: How long would you have to wait until the Vermilion Cliffs calved a boulder the size of a school bus, say? The answer: It could happen the day you sit down. But it's likelier that your descendants' descendants would still be sitting in that chair, many hundreds of generations later, waiting for the cliffs to crumble a little more. The rock is ancient, and so are the traces of erosion.

Millions of years ago, the spot where you're sitting would have been buried under the exposed layering of the present-day cliffs, under strata now called Moenkopi, Chinle, Moenave, Kayenta, and Navajo, each striation differing in color and resistance to erosion. The Paria Plateau has been retreating northwestward for eons, and these vivid cliffs mark its progress to date.

It's hard to believe that a national monument girded by towering cliffs—their color burning through the spectrum as the day advances—could be so little known. Yet few people have heard of the place, apart from one or two of its famous features. One reason is that Vermilion Cliffs National Monument is upstaged by its neighbors, which include some of the most famous national parks and monuments in the United States: Grand Canyon, Zion, Bryce Canyon, and more.

Another reason is the ruggedness of the terrain. Though located only a few miles from Lake Powell and its legions of pleasure craft, the 300,000 acres encompassed by the monument

In the Coyote Buttes, a natural column of rock called a hoodoo and nicknamed the Totem Pole towers against star tracks, revealing the passing of time along its banded length like the rings of a tree.





Sinuous lines of color swirl through the Wave, the monument's most famous landform. Flash floods carved this passage through petrified sand dunes, exposing the iron-rich bands.



are no place for the fainthearted or unprepared. "Exit the car, enter the food chain," quipped one official with the Bureau of Land Management, which administers the monument. The predators here are sun, heat, thirst, ignorance, and isolation. (Also rattlesnakes and scorpions.) There are almost no marked trails, only a few signposts, and none of the assurances, warnings, or rangers found in national parks. Here your cell phone doesn't work, you camp where you can, and the only water is what you carry.

The cliffs proper have been protected as wilderness since 1984. They form an irregular upside-down horseshoe, abrupt and sheer on the east side near the Colorado River, curving severely around to the south and shallowing on the west as they run up into Utah along House Rock Valley Road, one of the most beautiful dirt drives in the American West. Follow the arc of that horseshoe and the cliffs peer over you all the way, forbidding and beckoning at once.

But drive across the northern bench at the top of the horseshoe, heading from Page, Arizona, to Kanab, Utah, and you would never guess the cliffs are there. Hike out onto the Paria Plateau and you feel as though you're walking across an island in the sky. The cliffs are invisible below you, but you can sense their presence. This is what the world would be like if it were flat and ended precipitously at an edge in space. But when you come to the end of the plateau—high atop the Vermilion Cliffs—you see that the world still goes on, stepping its way shelf by shelf down to the Grand Canyon and beyond.

The Paria Plateau and its hem of cliffs were named a national monument by presidential proclamation in the year 2000, primarily in recognition of the exquisite archive of erosional forms—timescapes, windscapes, gravityscapes, and waterscapes but above all, sandscapes. There is the sand of the present day: the grit in your teeth, the slip-sink footing, the slithering tire-bog along the tracks in the Sand Hills mid-plateau. That sand (ancient enough, grain by grain) is derived from prehistoric sand—the Navajo sandstone that forms the plateau and cliffs. This sandstone, in turn, is the remains of a vast erg, a windblown sea of dunes that for millions of years covered most of what is now the Colorado Plateau. The geology is hard to imagine. It becomes even harder if you're lucky enough to come upon the Wave, hidden away in the northwest corner of the monument in a place called Coyote Buttes.

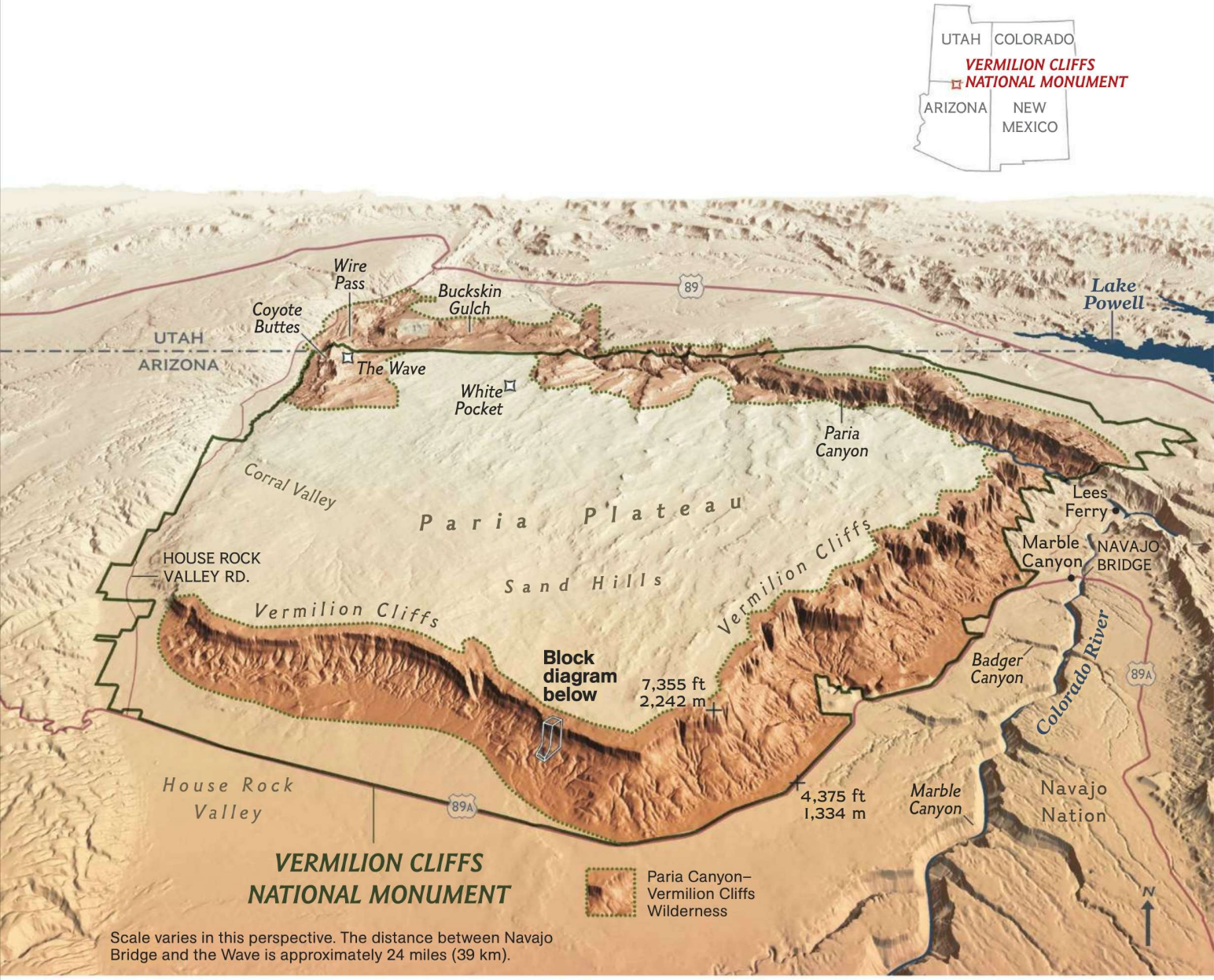
The Wave is a tumult of striped, fossilized dunes that look like petrified surf, forever rising and curving, towering just short of breaking. What's been left behind by long ages of erosion—rogue waves of smooth, banded sandstone in a bowl of light—is a record of chemical reactions taking place as the sandstone developed, with patterns of bleaching and the depositing of iron oxide and other minerals. In its sinuousness, the Wave forms a wind siphon, its geometry accelerating the wind the way a high, curving track accelerates a skateboarder.

Try to say the names of the colors you see glinting in the stone. They shift before you can do so. The sun pinwheels across the sky, clouds burgeon and fade, and the Wave evolves moment by moment without ever changing.

To safeguard this extraordinary formation, the BLM admits only 20 people a day to the Wave, so you're left nearly alone in a wilderness containing a geological "Mona Lisa." This isn't the South Rim of the Grand Canyon, a scenic view shared with thousands. Here is the intimacy of the senses: the abrasion of stone, the scent of rain on rock, a kaleidoscopic light that can leave you bewildered by the minute speck of time you occupy in the presence of so much frozen time.

The geological processes that shaped the Wave, as well as the cliffs and canyons and myriad landforms, continue unabated, of course. And yet they're hidden by the present. One afternoon I followed the dry creek bed of Buckskin Gulch on the west side of the monument, from a trailhead just off House Rock Valley Road. On the low hills around me lay bulging sandstone

Verlyn Klinkenborg is a frequent contributor. Richard Barnes has photographed Egypt's ancient whales and animal mummies for the magazine.



An age-old story, written in stone

Towering nearly 3,000 feet above the benchland below, the Vermilion Cliffs—named for their vivid red hue—reveal the layered history of an ancient landscape. Over millions of years, geologic processes turned waterborne sediments and windblown sand into five distinct rock formations, together spanning a vast slice of Earth's past. The Chinle layer is softer and more susceptible to erosion, undercutting the harder top layers. As they break off, the cliffs slowly retreat.

Exposed layers of the Vermilion Cliffs



MARTIN GAMACHE, NGM STAFF. BLOCK DIAGRAM: CHUCK CARTER
SOURCES: BRIAN GOOTEE, ARIZONA GEOLOGICAL SURVEY; BUREAU OF LAND MANAGEMENT; USGS



The Paria River cuts a deepening canyon through the plateau that shares its name. Petroglyphs on the canyon walls record the passage of Puebloans and other native peoples.



formations that looked like the pupae of some unaccountable insect. Tumbleweeds huddled in the creek bends like tired gray sheep.

Buckskin Gulch is famous for its slot canyon, but before I reached it I came to a high, perfectly undisturbed slope of loose red sand, as firm and uniform as the sand a wave leaves behind when it withdraws from a beach. Every grain seemed to know its place. It was sandstone in the making, uncongealed and awaiting diagenesis, the chemical transformation that would turn it into a slab of rock.

It's easy enough to see the stratigraphy in the layers of stone exposed on the cliff face, but there is also a stratigraphy of life-forms here, as well as a layering of human experience. Reach back far enough—190 million years and more, when this was a very different world—and you come to the ancient species, some crocodilian, some birdlike, that left their traces in the Navajo sandstone and in the formations that underlie it.

On the plateau, there are signs of more recent inhabitants in the few gnarled ranch structures up beyond a wire gate and into Corral Valley, high in the piñon and juniper. This landscape is not as spectacular as Coyote Buttes—almost nothing is—but it has its own private grace. Shallow basins in the sandstone catch every drop of rain. There are swales of arid grass and remnants of fence line that seem to exist only to keep the tumbleweeds in.

Thousands of years ago this landscape belonged to native hunters and gatherers, who must have passed through again and again. They were succeeded by the ancestral Puebloans, and later by the Paiute, who shared some of their knowledge of this country with a Mormon missionary named Jacob Hamblin. Hamblin, who settled in the House Rock Valley, knew the Vermilion landscape better than any other white man of his time. Explorer John Wesley Powell described Hamblin as a "silent, reserved man," adding that "when he speaks it is in a slow, quiet way that inspires great awe."

Hike down the Paria River Canyon, 38 wet-footed miles and at least four days from the trailhead to the Colorado River, and you come to the place where Powell and the battered remains of his first expedition camped on the night of August 4, 1869: the mouth of the Paria River, which Hamblin had described to Powell a year earlier. Preparing for his descent of the Colorado, Powell studied the terse account of Father Silvestre Vélez de Escalante, who, in 1776, tried to travel with his party from Santa Fe (in what is now New Mexico) to Monterey, California. He too camped near the mouth of the Paria River, hoping to find a more direct route back to Santa Fe. Powell described the cliffs in exuberant prose. Father Escalante said merely that the country had "an agreeably confused appearance."

Overwatching all these humans—itinerant or resident—would have been the birds now known as California condors *(Gymnogyps californianus),* which lived on the cliff edges high above. Generation after generation, they would have kept watch at intervals for at least the past 20,000 years—perhaps for as much as 100,000 years—diminishing as large Pleistocene mammals vanished. Condors have been missing from the Vermilion Cliffs since the early 20th century, but they are present again, reintroduced in 1996, their very small numbers supplemented by annual releases. From the condor viewing site on House Rock Valley Road, you're sure to see rocks high on the cliffs stained by their droppings.

How long until you see a condor? The good news is that the wait will take place in biological time, not geological time. While you're waiting—the Vermilion sun drying your flesh—you can imagine the sound of the wind in a condor's ears as it rises on an updraft and the view in its eyes as its head tilts from side to side, overwatching the plateau again. □

Condors disappeared from the Vermilion Cliffs region during the 1920s. Now they are back: More than a hundred have been reintroduced over the past 15 years. In the wilderness area northwest of the monument, the creek-bed trail through Wire Pass (right) starts out wide and shallow but narrows to a deep, tight slot. Seasonal dangers for hikers range from dehydration to drowning in flash floods.


California Condor
114"/9.5'/2.9m
Golden Eagle 85"/7.1'/2.2m
Red-tailed Hawk 50"/4.2'/1.3m

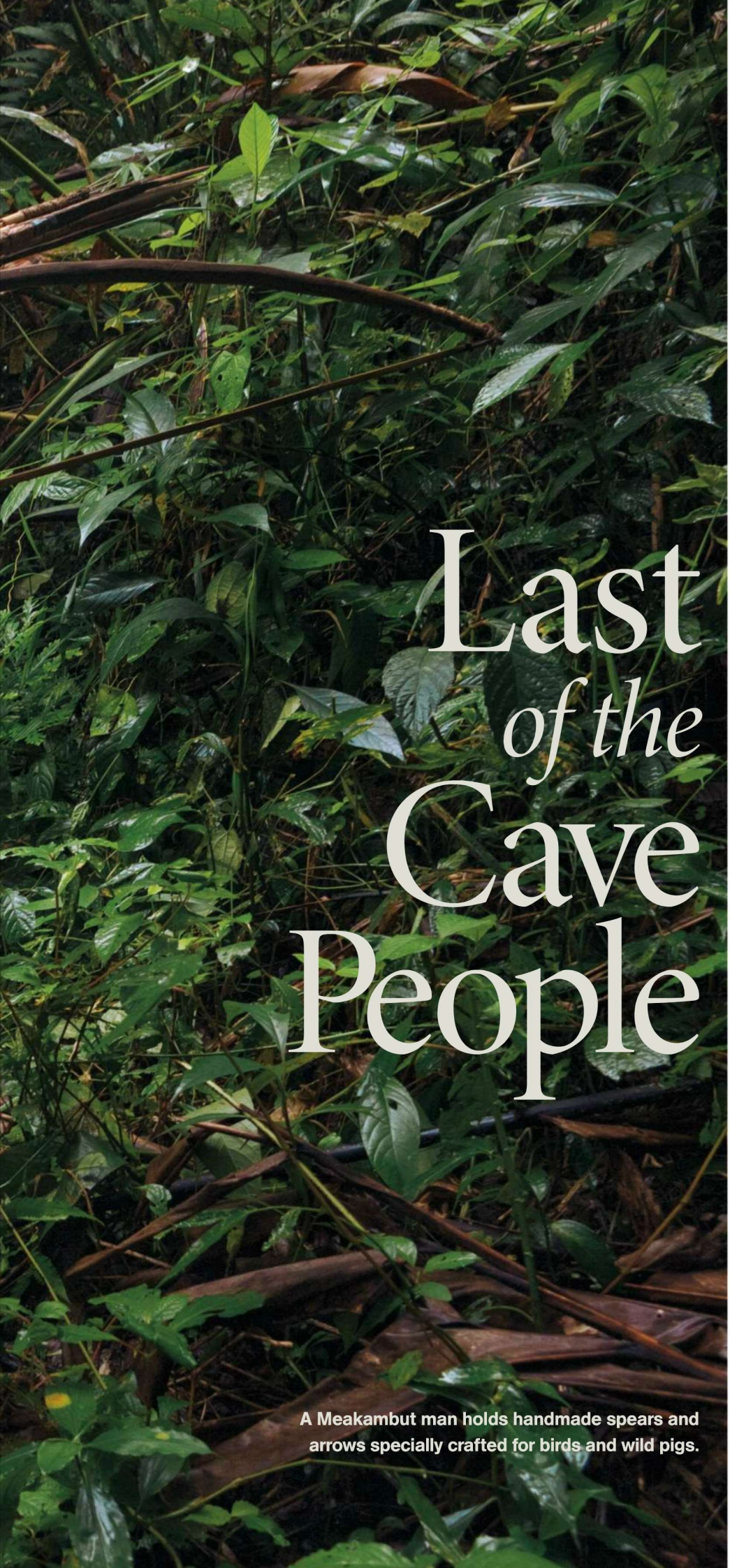




Welcome to the so-called Honeymoon Trail. Threading the hem of the Paria Plateau, Highway 89A partly traces a route followed by 18th-century Franciscan explorers, and by Mormons on their way to St. George, Utah, often to be married.







Last of the Cave People

A Meakambut man holds handmade spears and arrows specially crafted for birds and wild pigs.

A nomadic people in Papua New Guinea were rumored to be living in remote caves in the forest. When we found them, they sent a surprising message to the modern world.

By Mark Jenkins

Photographs by Amy Toensing



The Meakambut cook pancakes over an open fire using a regional staple: sago, a palm that produces a powder similar to cornstarch, and whose calories offer little protein and few vitamins.



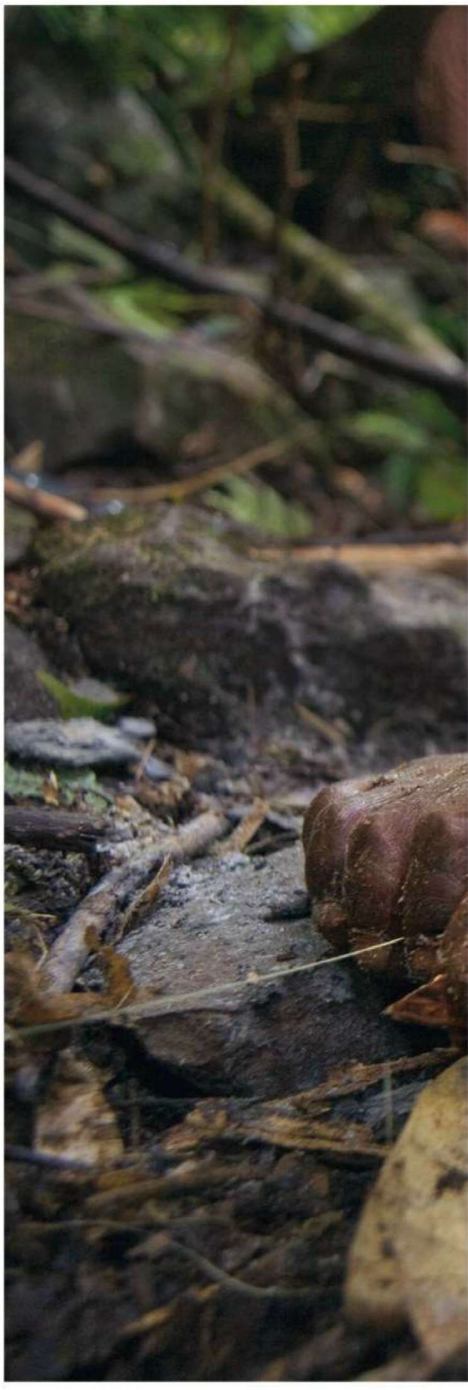
She is lying in a cave, dying.

Legs and arms but knobby sticks, Lidia Maiyu is curled up close to the campfire. Her eyes are wide in apprehension of death. She coughs, her body convulses, and she cries out in pain. Lidia is perhaps 15 years old, she isn't sure. Three months ago she gave birth, and the baby died; the group left the body in a cave and moved on. Pasu Aiyo, Lidia's husband, tells me this is what happens. "When you get sick, you get better or you die."

But for the glow from the campfire, it is impenetrably dark. Never are there stars, as if that would be too much to hope for. Instead, beyond the rock overhang, it's pouring, waves of water relentlessly slapping the giant fronds of the jungle. It always seems to rain at night here in the mountains of Papua New Guinea. This is why Lidia and what's left of her people, the Meakambut, seek refuge in rock shelters—they're dry. Located high in the cliffs, sometimes requiring a treacherous climb up vines, caves are also natural fortresses that once protected the Meakambut from their enemies: headhunters and cannibals and bride stealers. But that was generations ago. Now their enemies are less violent yet no less deadly: malaria, tuberculosis.

Pasu shoos away Biyi, their hunting dog, and sits down by the fire. He smooths his leaf loincloth and rests Lidia's head in his lap. She peers up at him wanly. Pasu gravely tells his brother John to ask us if there is anything we can do.

We—a team from National Geographic—have unwittingly walked into a crisis. Our plan, to follow the Meakambut, one of the last cave-dwelling, seminomadic peoples in Papua New Guinea, through their mountainous homeland, has been eclipsed by the present emergency. A member of our team, trained as an emergency medical technician, examines Lidia and discovers that her lungs are filled with fluid, her heart is thrumming at 140 beats a minute, and her temperature is 104. He determines that Lidia likely has a life-threatening case of pneumonia and gives her double doses of antibiotics and Tylenol. We coax her to drink a cup of sterilized water mixed with sugar and salt, sit her up for the night in her husband's arms so she can



Gripping a kindling-packed stick with his feet and using a strip of bamboo for friction, a Meakambut man coaxes a cooking fire from soggy terrain. This "fire saw" method is widely practiced throughout Papua New Guinea.



breathe more easily, and suggest that first thing in the morning she should be carried out of the mountains, then downriver, to a clinic in the village of Amboin. Two other Meakambut, Michael Wakinjua and his infant son, are also seriously ill.

One man from our team, Sebastian Haraha, is an ethnographer who has come on this journey to pinpoint the exact locations of the Meakambut's caves with a global positioning system. He hopes to register them under the National Cultural Property Act, so the homeland of the Meakambut will be protected from logging and mining. Now, in this moment of crisis, he volunteers to escort the sick all the way down.

At dawn Lidia is gasping for air. We administer more medicine and give Pasu a week's supply of pills. He bundles Lidia's lax body into a *bilum,* or net bag, and slings her onto his back. Sebastian

helps Michael, while Michael's wife carries their listless baby on her back. Like wounded refugees from a jungle war, they depart single file down the slippery path. It will take them six hours to machete their way to the Manbungnam River, where we have a dugout canoe with an outboard motor waiting. From there it's another six hours downstream to reach the clinic. We have little hope that Lidia will live.

THE VAST GEOGRAPHIC VARIATION OF Papua New Guinea created tremendous biological diversity, which in turn was accompanied by enormous cultural diversity: more than 800 languages in a country about the size of California. Due to this diversity, after colonial powers prohibited headhunting, cannibalism, and tribal warfare beginning in the 1880s, the region became a draw for both missionaries and anthropologists. Margaret Mead made her name here, as did Gregory Bateson (Mead's third husband) and, more recently, the writer Jared Diamond.

Today the whole country continues to conjure images of headhunters with bows and arrows, and bones through their noses. But that's about as accurate as imagining the American West filled with Indians still taking scalps. Many photos of feathered and painted Papua New Guineans come from tourist exhibitions akin to Native American powwows.

It is only in the most deeply inaccessible regions of the country that enclaves of traditionally nomadic people, like the Meakambut, still exist. The group lives on two steep ridges hidden on the edge of the expansive northern escarpment of the Central Range. Boundaries between their land and the territories of surrounding settlements—Imboin, Awim, Andambit, Kanjimei, and Namata—are roughly demarked. Their territory is about a hundred square miles.

The Meakambut were unknown to the outside world until the 1960s, when Australian patrols began to trek into the country's most ferocious topography. In 1991 Slovenian anthropologist Borut Telban spent a week in the area and found only 11 Meakambut living in roughly built shelters and caves. He recounted that the men wore kina-shell necklaces and leaf loincloths, and the women wore grass skirts. When Telban returned in 2001, he couldn't locate them again. But the related Awim people knew that the Meakambut were still up there somewhere. Only three generations back the Awim had also followed a nomadic lifestyle, but they have since settled beside the Arafundi River to gain access to schools and clinics.

In hopes of meeting up with these last seminomadic holdouts, an anthropological researcher named Nancy Sullivan sent out a team in July 2008 to find the Meakambut and inventory their caves. Sullivan, who runs a consulting firm in Papua New Guinea that conducts social assessments for development projects, is studying the region's cave paintings—hand stencils that record generations of inhabitants. With blue eyes and flowing white-blond hair, Sullivan bears a passing resemblance to Meryl Streep. She has lived in Papua New Guinea for more than two decades and has adopted a number of local children. Sullivan's team discovered 52 surviving Meakambut and 105 caves with names, only a score of which were actively used as shelters. They found clay pots, bone daggers, and hand stencils on the walls in nine caves, and human skulls in three. Many of the elderly had died.

TO FIRST SEARCH FOR the Meakambut, our team flies by bush plane into the Sepik River basin, the floodplain that drains northwest Papua New Guinea. We then skim up smaller and smaller tributaries in a motor dugout until we are pushing it more than riding in it. Finally we strike out on foot into the mountains.

Two evenings in a row we try reaching them by jungle telephone: Three men pound the two-story trunk of a towering tree with wooden bats, the deep-voiced thumps reverberating out over the canopy. When this doesn't work, we set out on a grueling two-day foot patrol to the group's last known whereabouts, Tembakapa,

Mark Jenkins wrote about land mines in Cambodia in last month's issue. Photographer Amy Toensing is currently documenting the Aborigines of Australia.

PEOPLE OF THE HILLS

The Meakambut are among the most reclusive of the Sepik region's peoples, clinging to the solitude of highland caves while other groups have settled in lowland villages. The territory of the Meakambut is hard to define, since they are seminomadic.



Central Range
Mt. Macgregor
6,388 ft
1,947 m
ENGA
EAST SEPIK
Andambit
Kopao cave
Ulapunguna cave
Tembakapa
Wakau camp
Maramuni
Arafundi
Yuat
Namata
Karawari
Manbungnam River
Imboin
Awim
4°45′S
Arafundi
MEAKAMBUT TERRITORY
(approximate)
Yamandim
Wombrumas
143°50′E
Yimas I
Kanjimei
Imanmeri
Yimas Lakes
Yimas II
Asangamut
Konmei Creek
Amboin
Ambonwari
Kundiman
Lake Virginia
Konmei
Sepik River Valley
143°30′
Karawari
Yuat
N
Groups who moved closer to the lowlands were seeking access to schools, clinics, and markets.
Scale varies in this south-facing perspective. The distance between Amboin and the summit of Mount Macgregor is approximately 28 miles (45 km).
143°40′
Biwat

MARTIN GAMACHE AND MAGGIE SMITH, NGM STAFF

SOURCES: ANTON LUTZ, LCMS WORLD MISSION; PAUL ROSCOE, UNIVERSITY OF MAINE; NANCY SULLIVAN; SUMMER INSTITUTE OF LINGUISTICS-PAPUA NEW GUINEA; BORUT TELBAN, SLOVENIAN ACADEMY OF SCIENCES AND ARTS; UNIVERSITY OF PAPUA NEW GUINEA REMOTE SENSING CENTRE



For generations people in the region have marked cave walls with stenciled handprints. These prints were made with clay-based paint, but in other caves, crimson stains tell the story of a bloody initiation ritual for young men.

a collection of temporary huts perched on a misty ridge. It is deserted. In the middle of the huts is a wooden cross encircled with stones.

At noon the next day, two Meakambut men come striding into our camp—they've heard the call of the jungle phone. They recognize 26-year-old Joshua Meraveka, a member of Sullivan's team at the time, and greet him joyously, vigorously shaking his hand. He introduces them as John and Mark Aiyo—brothers, perhaps in their late 20s, both slight, muscled, with wide feet. John, a leader of the Meakambut, is wearing a blue Lakers jersey, a leaf loincloth, and a beaded headband festooned with yellow feathers. Mark has striped his face with charcoal and red clay and placed ferns in his hair and yellow flower petals in his black beard.

They lay down their bows and arrows and machetes, squat by the fire, and begin rolling tobacco leaves for a smoke. Because we are with Joshua, our presence doesn't seem to bother them. He explains they have Christian names because some of their people lived in villages for a time; one had gone to a Bible school and baptized them when he returned. John and Mark are from the 12-member Embarakal group, one of perhaps four that compose the Meakambut. The other three groups have had to leave to take their sick to a health clinic over the mountains (rather than to the one down the river). "Too many people sick," says John through Joshua. The rest of the Embarakal,

We try reaching the reclusive group by jungle telephone: pounding the trunk of a towering tree with wooden bats.

some of whom are also very sick, he says, are coming down to a cave called Ulapunguna tomorrow to meet us.

We set out for Ulapunguna cave at nine the next morning, Mark in the lead. The trail is a web of vines, but Mark glides like a phantom right over them. He points his toes, like a ballerina, confidently gripping root, rock, or mud. Leeches are everywhere, and he stops periodically to shave them off his bare legs with his machete.

Finally we reach Ulapunguna, a rock overhang 40 feet high with fire pits and a quiver of arrows lined up against the wall. The featherless arrows are four feet long. Each has a point designed for a different prey. There are three arrows for fish, two for birds, two for pigs. When I ask how often they kill a pig, John says every week. It is clear he is proud to be a hunter. Mark says that "being a nomad is in our blood." And who is the intended prey for the arrow with a carved hardwood point and a foot of sharp, backward angling notches? Mark smiles, then thumps his chest once with his fist and dramatically falls over.

While waiting for the rest of the Embarakal to arrive, John begins to replace his bowstring and, through Joshua, explain cave life to me. The Meakambut spend several days to several weeks in any rock shelter or hut before moving on. The women and children plant taro, pumpkins, cucumbers, cassava, bananas, and tobacco, to be harvested the next time they pass through. The men hunt or help the women make flour from sago palms. He says they like their hunter-gatherer life and have no interest in changing it.

Each of their caves has an owner and a name, and ownership is passed down from father to son. Mark and John own Ulapunguna cave. Some caves have legends, which are strictly proprietary: Only the cave owner can share its secrets.

Plucking his new bamboo bowstring, John indicates for me to follow him. We track through the jungle to a clearing, where he points up at a massive limestone wall.

"Kopao," he says.

Kopao is the Meakambut's most sacred cave. It is their creation cave, where they believe they originated, and John says he is the owner of this cave too. He will take me there tomorrow. When we return to Ulapunguna, the rest of the group has arrived. This is when we first encounter Lidia, curled up by the fire, coughing horribly.

THE FOLLOWING DAY, while the sick begin their long journey to the clinic, I head to Kopao cave with John and Joshua. The trail ascends a flash flood gulley, abruptly ending at a vertical face. Without hesitation, John starts climbing the slick black stone, his toes finding pockets in the limestone. Eventually he finds a small tree protruding perpendicular to the face, knots a vine around the trunk, and lowers the end to me. I climb up hand-over-hand, feet slipping against the wet wall. We monkey up two more bands of slimy rock via slick vines before I insist we use a rope. It takes us more than two hours to climb a thousand feet. We crawl through tree limbs hanging out in space. The final test is a tiptoe traverse along a glass-smooth ledge with nothing but an abyss of swirling mist beneath us.

On the other side is Kopao cave. We hunch beneath a low overhang and stumble into a gantlet of skulls. Human skulls. They are lined up as though they are whispering to each other. Their craniums have turned green and their dark, haunting eye sockets stare directly at intruders. John is conspicuously silent. He slides his machete into his bark belt. These are the skulls of his ancestors. The Meakambut may have Christian names, but they continue to engage in ancestor worship. As if trespassing, he delicately slips past the ossuary of skulls.

Farther along the cave are the paintings,



The Meakambut move through their environment with constant vigilance, always seeking sources of food. The nearby rivers offer small fish that the men catch with wooden spears.





Pasu Aiyo carries his pneumonia-stricken wife, Lidia, 15, on the two-day trek to the nearest health clinic. "The life of a nomad is hard," the group's leader, John Aiyo, tells a translator. "Traveling across the mountains is very tiring."

red and black stencils of human hands. These are the prints of John's forebears. He doesn't know how old they are—they keep no record of time—but many of the prints have almost disappeared. Like the skulls, the hand stencils seem to be saying, Stop, turn around, leave now.

John leads me past the paintings to an eight-inch-wide crack in the ceiling. He stands beneath it and solemnly says that he will now tell the story of Kopao, but when he is done, we must leave immediately, quickly and silently.

In the beginning, Api, the Earth spirit, came to this place and found the rivers full of fish and the bush full of pigs, and many tall sago trees, but there were no people. Api thought: This would be a good place for people, so he cracked the cave open. The first people to pull themselves out were the Awim, and then the Imboin and other groups, and finally the Meakambut. They were all naked and could barely squeeze out into the light. Other people were inside, but after the Meakambut came out, Api closed the crack, and the others had to stay behind in darkness.

The Awim and the Imboin and the Meakambut spread across the mountains and lived in rock shelters. They made stone axes and bows and arrows, and the hunting was good. There was no hatred, no killing, no disease. Life was beautiful and calm, and all people had full stomachs.

Society Grant Nancy Sullivan's work was funded in part by your National Geographic Society membership.

The next morning John is agitated. The skulls had seen him tell the secret story to the white man. They are angry.

At this time men and women lived in separate caves, John continues. In the evening, the men would go up to a special cave to sing. But one night a certain man pretended he was sick and stayed behind. When he could hear the men singing, he snuck down to the women's cave and had sex with a woman.

When the men returned, they sensed something was wrong. One man suddenly felt jealousy, another felt hatred, another felt anger, and another felt sadness. This is when man learned of all bad things. This is also when sorcery began.

THE NEXT MORNING, back in Ulapunguna, John is sitting on his haunches, hands over the fire, head down. There are no flowers or ferns in his curly black hair. He is deeply agitated.

Joshua says the spirits of Kopao came to John in the night. The skulls spoke to him. The black sockets had red eyes like some nocturnal bush creature. The skulls said they had seen John bring a white man into the sacred place. They had heard John tell the secret story to the white man, and they were angry. This was a story for the Meakambut, not for the white man.

John is worried that the spirits might punish him by killing Lidia. He has a bad feeling. He wants to leave immediately, run out of the mountains to the river and paddle downstream to wherever she is. I am to blame for his fears and feel as if I have betrayed these people.

Belief in sorcery and witchcraft is common throughout Papua New Guinea. Amnesty International cites media reports stating that 50 people accused of sorcery were murdered in 2008; some were burned alive. British author Edward Marriott describes in his 1996 book, *The Lost Tribe,* how he was blamed when a woman and four children were killed by a lightning strike, and he was forced to flee for his life. If Lidia dies, it is likely that I will be blamed.

We explain to John that paddling downstream will take several days and that our motor dugout is expected back upstream tomorrow, when we can take him to the clinic in Amboin. Satisfied with the plan, John surprises us by admitting that his people ran out of food yesterday, so today they must make sago. When I suggest we go hunting instead, he shakes his head.

We follow Mark and his wife, Jelin, to the sago camp. Making sago is an arduous operation. Mark hacks out pulp from the heart of a felled palm tree; the pulp is transferred to a trough filled with water, and Jelin squeezes it against a coconut-husk filter, pressing out an orangish white paste. The group works for six hours, glistening with sweat, slowly fatiguing. By late afternoon they've collected 40 pounds of gummy sago—not bad for an afternoon's work—and we head back to Ulapunguna as the rain begins.

That night it's fire-fried sago pancakes for dinner. Sago is a carbohydrate with essentially no protein, fat, vitamins, or minerals. Although John had made it clear they were proud to be hunters and that they shot a pig every week, we haven't seen any meat.

John, Joshua, and I sit by the fire, chewing the bland, gummy pancakes, talking late into the night. John begins to let down his guard. He admits that his group hasn't eaten meat or killed a pig for over three months. He is deeply worried for his people. He says that there used to be several hundred Meakambut. Now they lose two babies for every one that lives. He says that there are no pigs left in the mountains, no cassowaries in the jungle, no fish in the streams. When the campfire dies out, John whispers something he wants me to pass on to the government of Papua New Guinea. It is a message.

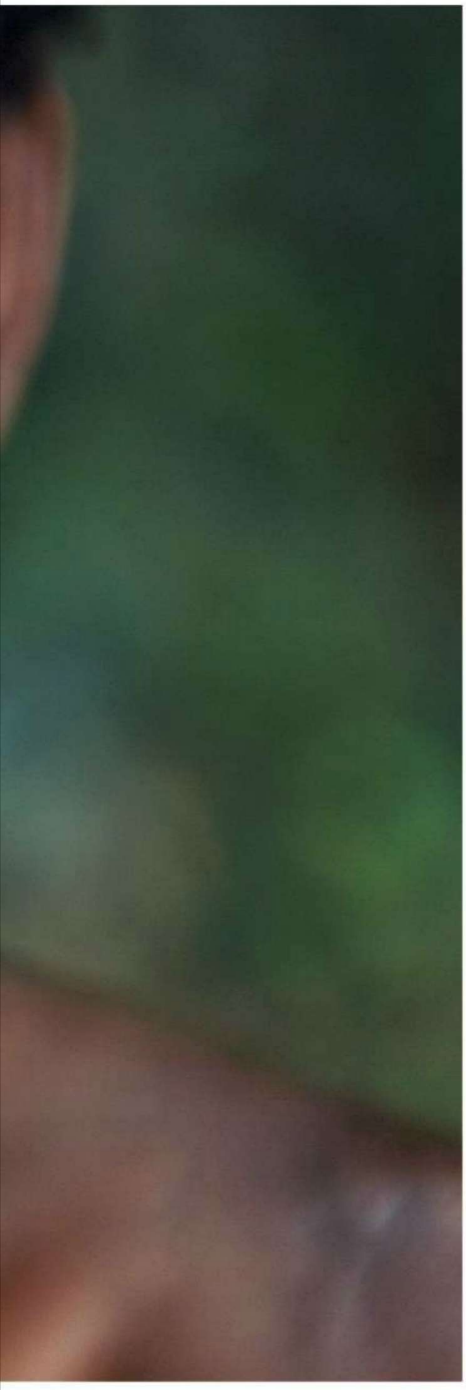
JUST AFTER DAYBREAK the Embarakal group begin decorating themselves for the journey



out of the mountains. The men stripe their faces with black and orange; the women blanket their skin with dots. In a climate where clothes are superfluous, this is how you dress up for special occasions.

We reach a camp called Wakau, halfway to the river, by noon. Resting here in the oppressive heat, we suddenly catch human hoots drifting down from the mountains—it is the rest of the Meakambut returning over the ridge. The Embarakal group decides to join them, and John asks me to find Lidia, Michael, and the baby and send them home when they are well. Privately, I am relieved that John is not coming with us. I worry what would happen if Lidia has died.

We reach the motor dugout late in the afternoon and travel downstream until dark,



Pasu Aiyo is proud of his people's traditions, as his flower-bedecked beard proclaims. But nomadic life takes a toll, and illness often proves fatal. Many Meakambut wonder if settling in a village would offer a brighter future.

eventually reaching the riverside village of Awim. Stepping from the dugout, we are shocked to learn that Lidia and the others are all here. The only working clinic in the region had no supplies to help her.

But Lidia is still alive. Simple antibiotics have saved her. She is still weak and unable to walk, so we put her on an IV drip for the night. Michael and his son are recovering as well. By dawn, Lidia is able to smile and rise unsteadily to her feet, although she is still hacking.

At breakfast, I find Sebastian Haraha sitting by the campfire. He hands me a cup of coffee and motions for me to sit beside him. He was compelled to temporarily abandon his plan of mapping the Meakambut's caves—the goal of which is to save their habitat, and thus ensure the continuation of their culture in the future—in order to save their lives in the present. He says the choice was clear. He is a human first, an ethnographer second.

"Protecting the caves? What does it matter—if there are no Meakambut left?" asks Sebastian. He is angry. Lidia's close call has shaken him.

"The Meakambut are on the edge of extinction. They are dying from easily treatable illnesses. In ten years they could be completely gone, and their culture and language would vanish. This is one of the last nomadic people in Papua New Guinea!"

He is obviously appalled, but also energized.

"When I get back to Port Moresby, I'm going to walk straight into the prime minister's office and do something." I nod in agreement, then pass along John's message verbatim:

"We, the Meakambut people, will give up hunting and always moving and living in the mountain caves if the government will give us a health clinic and a school, and two shovels and two axes, so we can build homes." □

EPILOGUE *Since National Geographic's visit, the Meakambut continue to live without access to government services. But they have partly settled in homes on the ridgetop camp of Tembakapa, where Nancy Sullivan's team has provided building supplies, water tanks, and solar panels. Despite the threat of encroachment by miners, they continue to hunt and gather on their traditional land. Lidia survived.*

NG CONNECT

Every month this page features our staff picks of National Geographic Society products and events. For more go to *nglive/events.org.*



EXHIBITS

Celebrate 100 Years of Washington, D.C.'s Cherry Blossoms

Society board member and writer Eliza Scidmore helped bring cherry blossoms to the nation's capital. See her photographs from Japan, including this one (right). A second exhibit explores the samurai. Both open March 7 in Washington at National Geographic. Visit *ngmuseum.org.*

LECTURE

ROZ SAVAGE The adventurer who left her office job to become an ocean rower speaks on February 21 in Dallas, Texas. See *nglive.org.*

TRIP



ALASKA'S INSIDE PASSAGE Journey north to experience the beauty of Alaska. Cruise through fjords, whale-watch, spend a day in Glacier Bay National Park and Preserve, and learn about the people who call Alaska home during this eight-day expedition. All departures are accompanied by a team of experts. For details go to *ngexpeditions.com/alaska.*

APP

WEIRD BUT TRUE Did you know a sneeze travels a hundred miles an hour? Find this and other tidbits in our kid-friendly collection of mind-blowing facts. In the App Store now.

BOOK

ULTIMATE HIKER'S GEAR GUIDE Suit up the right way before hitting the trails. Extreme trekker Andrew Skurka provides expert advice on everything from boots to backpacks for hikers of all levels in this new book. Available February 21 ($19.95).



Free Download of the Month



Toubab Krewe *TK2*

Some sounds don't fit neatly into preexisting categories. This is the music of Toubab Krewe, an instrumental powerhouse based in Asheville, North Carolina. Swirling together rock, African traditions, jam-band sensibilities, and international folk strains, the band creates a sonic Pangaea. Download a song at *natgeomusic.net/free.*

PHOTOS: ELIZA SCIDMORE, NATIONAL GEOGRAPHIC STOCK (TOP); RALPH LEE HOPKINS (RAFT)

A Dog's Best Friend

Weimaraners are virtually synonymous with William Wegman. He's photographed them in dresses and in boots, as letters of the alphabet, and in their full, natural splendor. When Stephanie Sinclair set out to create a portrait of the man behind so many beloved canine portraits (and the cover of this issue), she was surprised to find his dogs—Bobbin, Flo, Penny, and Candy (below)—behaving as rambunctiously as her own pug-Boston terrier mix. The photographers shared pet-owner tips during a stroll in New York City. "It was a treat," says Sinclair, who's often tackling gender and human rights issues in strife-ridden areas. "It was nice to be able to shoot something beautiful and joyful." *—Luna Shyr*



BEHIND THE LENS

Where was this photograph taken?

SS: It was in Wegman's living room at the end of the day. The dogs had just gone for a walk and eaten. I was surprised at what good shape his furniture was in. My couch is all torn up because of my dog. I asked, "How does your furniture look so good?" If you look closely at the couch, you'll see there are little dog faces. He designed that pattern, and the fabric is extra thick and stain resistant.

What did you hope to capture when you set off on this assignment?

I wanted to show how much his dogs are a part of his family. They're everywhere—they follow him from room to room to room. They're always waiting for what he's going to do next. They *love* him; I wanted to show that. He went over to the couch, and they all jumped on; they just curled around him. I think it's funny that when you look at Wegman's photographs, the dogs look super well behaved. But in person they're like regular dogs—they're getting into stuff. The new one, who's only six months old, was always biting the others. They were sniffing everything and going in four different directions.

PHOTO: STEPHANIE SINCLAIR



The Hole Thing Pointers named Tyree and Skeeter poke through portholes in a Plymouth. Notes accompanying the photograph—which was published in a 1958 National Geographic book about dogs—say the animals' owner, E. D. Todd of Victoria, British Columbia, installed the openings in the trunk "to give dogs light and air when he went driving." Though probably not the safest arrangement for the pets in case of accident, it likely did cut down on the dog hairs in the car's back seat. Their coats may be short and slick, but pointers can be prodigious shedders. *—Margaret G. Zackowitz*

Flashback Archive Find all the photos at **ngm.com.**

PHOTO: WIDE WORLD PHOTOS, INC/NATIONAL GEOGRAPHIC STOCK

NATIONAL GEOGRAPHIC (ISSN 0027-9358) PUBLISHED MONTHLY BY THE NATIONAL GEOGRAPHIC SOCIETY, 1145 17TH ST. NW, WASHINGTON, DC 20036. ONE YEAR MEMBERSHIP: $34.00 U.S. DELIVERY, $38.00 TO CANADA, $49.50 TO INTERNATIONAL ADDRESSES. SINGLE ISSUE: $7.00 U.S. DELIVERY, $10.00 CANADA, $15.00 INTERNATIONAL. (ALL PRICES IN U.S. FUNDS; INCLUDES SHIPPING AND HANDLING.) PERIODICALS POSTAGE PAID AT WASHINGTON, DC, AND ADDITIONAL MAILING OFFICES. POSTMASTER: SEND ADDRESS CHANGES TO NATIONAL GEOGRAPHIC, PO BOX 63002, TAMPA, FL 33663. IN CANADA, AGREEMENT NUMBER 40063649, RETURN UNDELIVERABLE ADDRESSES TO NATIONAL GEOGRAPHIC, PO BOX 4412 STN. A, TORONTO, ONTARIO M5W 3W2. UNITED KINGDOM NEWSSTAND PRICE £4.99. REPR. EN FRANCE: EMD FRANCE SA, BP 1029, 59011 LILLE CEDEX; TEL. 320.300.302; CPPAP 0715U89037; DIRECTEUR PUBLICATION: D. TASSINARI DIR. RESP. ITALY; RAPP IMD SRL, VIA G. DA VELATE 11, 20162 MILANO; AUT. TRIB. MI 258 26/5/84 POSTE ITALIANE SPA; SPED. ABB. POST. DL 353/2003 (CONV L.27/02/2004 N.46) ART 1 C. 1 DCB MILANO STAMPA QUAD/GRAPHICS, MARTINSBURG, WV 25401. MEMBERS: IF THE POSTAL SERVICE ALERTS US THAT YOUR MAGAZINE IS UNDELIVERABLE, WE HAVE NO FURTHER OBLIGATION UNLESS WE RECEIVE A CORRECTED ADDRESS WITHIN TWO YEARS.



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